OIL SHALES OF THE ALBERT FORMATION, NEW BRUNSWICK

Open File Report 82-12

ISSN 0712-4562

NATURAL RESOURCES
NEW BRUNSWICK
RESSOURCES NATURELLES
NOUVEAU-BRUNSWICK

GOVERNMENT OF CANADA
REGIONAL ECONOMIC
EXPANSION

GOVERNMENT OF CANADA
INSTITUTE OF SEDIMENTARY AND
PETROLEUM GEOLOGY

This report has been prepared
under contract for:

Mineral Resources Division
Department of Natural Resources
Province of New Brunswick

Hon. J. W. Bird, Minister

and

Geological Survey of Canada
Institute of Sedimentary and
Petroleum Geology, Calgary

Hon. Marc Lalonde, Minister

Funding provided by:

Government of Canada
Regional Economic
Expansion

Hon. Herb Gray, Minister

Geological Survey of Canada
Institute of Sedimentary and
Petroleum Geology, Calgary

Hon. Marc Lalonde, Minister

OIL SHALES OF THE ALBERT FORMATION, NEW BRUNSWICK

Mineral Resources Division
Department of Natural Resources
New Brunswick

"This is a Federal-Provincial Development Project, funded in part under the Minerals and Fuels, Subsidiary Agreement of the Canada-New Brunswick General Development Agreement by the Government of New Brunswick and the Department of Regional Economic Expansion."

Copies available by contacting:

Mineral Resources Division
Department of Natural Resources
P.O. Box 6000, Fredericton, N.B.
E3B 5H1; or

Institute of Sedimentary and
Petroleum Geology
3303-33rd Street N.W.
Calgary, Alberta
T2L 2A7

Report No.: Open File
Report 82-12

Authors: G. Macauley
Calgary, Alberta

F. D. Ball, Three-D
GeoConsultants Ltd.
Fredericton, N. B.

Cover: Tim Fevens

Catalogue No.: ISSN 0712-4562

TABLE OF CONTENTS

	Page
Table of Contents	i
List of Figures	ii
List of Tables	iv
List of Plates	iv
List of Appendices	vi
Abstract	ix
Introduction	1
Acknowledgements	4
Stratigraphy	6
Lithology	15
Dolomite marlstone	15
Laminated marlstone	16
Clay marlstone	17
Summary	19
Mineralogy	20
Dolomite	25
Calcite	25
Siderite	25
Quartz-Feldspar	26
Clays	26
Analcime	27
Others	28
Structures	30
Primary sedimentary structures	31
Imposed diastrophic structures	32
Concepts of economic evaluation	34
Visual inspection	34
Geophysical logs	36
Density vs. yield	37
Density log	41
Organic geochemistry	41
Fischer assays	42

Page

Shale oil yield..... 43
Shale oil gravity..... 44
Water yield..... 45
Organic carbon..... 45
Rock-eval pyrolyses..... 48
Kerogen..... 48
Hydrocarbon potential..... 52
Production index..... 53
Specific site evaluations..... 58
Albert Mines..... 58
Boudreau..... 64
Dover..... 67
Rosevale..... 69
Urney..... 72
Summary..... 75
References..... 80
Plates..... 83
Appendices..... 89

FIGURES

Figure 1. Tectonic elements of the Fundy Basin, New Brunswick-Nova Scotia..... 7

2. Outcrop distribution of Albert Formation, Moncton subbasin-Kingston Uplift, New Brunswick..... 8

3. Carboniferous nomenclature and correlations, Moncton subbasin, New Brunswick..... 11

4. Albert Mines area, core hole logs..... pocket

5. Urney-Rosevale and Boudreau-Dover areas, core hole logs..... pocket

6. Mineral distribution from X-ray diffraction analyses for a) Boudreau, Dover, Urney, Albert Mines..... 22

Page

b) Albert Mines..... 23
c) Albert Mines, Rosevale..... 24

7. Rock density vs. Fischer assay yields, Albert Mines area:
a) Upper Zone..... 38
b) Albert Mines Zone..... 38
c) Clay Marlstone Zone..... 39
d) Dolomite Marlstone Zone..... 39

8. Comparative density vs. yield averages for lithologic sub-units, Albert Mines area..... 40

9. Fischer assay yield vs. organic carbon content, Albert Mines area:
a) Upper Zone..... 47
b) Albert Mines Zone..... 47
c) Clay Marlstone Zone..... 47
d) Dolomite Marlstone Zone..... 47

10. Fischer assay yield vs. organic carbon content,
a) Can. Oxy. Rosevale 1..... 48
b) AtlanticRichfield Boudreau 1..... 48

11. Hydrogen index vs. oxygen index, Rock-eval pyrolyses,
a) Albert Mines area..... 50
b) Urney-Rosevale area..... 51
c) Boudreau-Dover area..... 51

12. Hydrocarbon Potential (Rock-eval) vs. Fischer Assay yields, Albert Mines area..... 53

13. Diagrammatic comparison of total carbon, Rock-eval Pyrolyses, and Fischer Assay results,
a) Can. Oxy Albert Mines 5..... 54
b) Can. Oxy Rosevale 1..... 55
c) AtlanticRichfield Boudreau 1..... 56

14. Interpreted surface geology, Albert Mines area, with subsurface contours in the Albert Mines Zone..... 59

15. Lithologic correlation section, Albert Mines area..... 60

Page

16. Structural attitudes of oil shale beds in tunnels at Albert Mines (after Wright, 1922)..... 62

17. Structural interpretation, Boudreau area..... 66

18. Structural interpretation, Dover area..... 68

19. Correlation section with structural interpretation, Rosevale area..... 70

20. Correlation section with structural interpretation, Urney area..... 73

TABLES

Table 1. Average hydrocarbon yields from the lithologic sub-units of the Frederick Brook Member, Albert Mines area..... 63

2. Estimated in situ reserves to a depth of 600 m vertical (730 m on zone surface)..... 64

3. Average hydrocarbon yields from the lithologic sub-units of the Frederick Brook Member, Rosevale area..... 71

PLATES

Plate 1. a) Atl.Rich. Boudreau 1, 300.2m (985'): discontinuous organic laminae in a dolomitic marlstone; upper shale z. - Fred.Brk.M.
b) Can.Oxy. A.M. 6, 327.4m (1074'): discontinuous organic laminae grading up to continuous fine laminae in a dolomitic marlstone; dolomite marlstone z. - Fred.Brk.M.

Page

c) Can.Oxy. A.M. 6, 330.1m (1083'): massive silty dolomitic marlstone; dolomite marlstone z. - Fred.Brk.M.
d) Atl.Rich. A.M. 1A, 348.7m (1144'): continuous organic laminae in a dolomitic marlstone displaying penecontemporaneous deformation structures including load and slump structures and soft sediment brecciation; dolomite marlstone z. - Fred.Brk.M.
e) Atl.Rich. A.M. 1A, 48.3m (1585'): discontinuous organic laminae in a silty dolostone displaying "rip-up" breccia and load structures; dolomite marlstone z. - Fred.Brk.M.
f) Atl.Rich. A.M. 1A, 303.3m (995'): discontinuous organic laminae in a dolomitic marlstone displaying load structures in the form of pseudonodules; dolomite marlstone z. - Fred.Brk.M..... 83

2. a) Can.Oxy. A.M. 7, 119.5m (392'): deformed bedding, due to folding of a laminated dolomitic marlstone; Albert Mines z. - Fred.Brk.M.
b) Atl.Rich. A.M. 1A, 11.6m (38'): fissile, organically laminated (varved) dolomitic marlstone; upper shale z. - Fred.Brk.M.
c) Can.Oxy. A.M. 2, 157.6m (517'): calcite stringers parallel to high angle bedding in a laminated dolomitic marlstone; Albert Mines z. - Fred.Brk.M.
d) Can.Oxy. A.M. 2, 176.2m (578'): calcite stringers in a laminated dolomitic marlstone displaying both penecontemporaneous and structural deformation features; Albert Mines z. - Fred.Brk.M.
e) Can.Oxy. A.M. 2, 174.0m (571'): calcite stringers in a bedded to laminated dolomitic marlstone displaying deformed bedding; Albert Mines z. - Fred.Brk.M.
f) Atl.Rich. Boudreau 1, 312.7m (1026'): deformed and brecciated bedding of a bedded to laminated dolomitic marlstone; upper shale z. - Fred.Brk.M..... 85

Page

3. a) Atl.Rich. A.M. 1A, 483.1m (1585') (p.p.l.): minor "flecks" of organic material (black, elongate) and quartz grains (white, equidimensional) in a carbonate groundmass of a silty dolostone; dolomite marlstone z. - Fred. Brk.M.
b) Atl.Rich. A.M. 1A, 483.1m (1585'): organic laminae (dark grey) of a "rip-up" clast in a silty dolostone; dolomite marlstone z. - Fred.Brk.M.
c) Atl.Rich. Boudreau 1, 300.2m (985') (p.p.l.): discrete organic laminae (dark grey) in a dolomitic marlstone; upper shale z. - Fred.Brk.M.
d) Atl.Rich. A.M. 1A, 11.6m (38') (p.p.l.): organic material forming both matrix, with carbonates and laminae in varved dolomitic marlstone; upper shale z. - Fred.Brk.M.
e) Can.Oxy. A.M. 6, 330.1m (1083') (p.p.l.): organic laminae disrupted and distorted by quartz grains in a silty dolomitic marlstone; dolomite marlstone z. - Fred.Brk.M.
f) Can.Oxy. A.M. 2, 176.2m (578') (p.p.l.): deformed bedding displayed by oriented organic "flecks" (black, elongate) and laminae of varying quantity of organic content (light to dark grey); Albert Mines z. - Fred. Brk.M..... 87

APPENDICES

Appendix 1. Core descriptions..... 89
AtlanticRichfield Albert Mines 1A..... 89
Canadian Occidental Petroleum Albert Mines 2..... 96
Canadian Occidental Petroleum Albert Mines 4..... 98
Canadian Occidental Petroleum Albert Mines 5..... 102
Canadian Occidental Petroleum Albert Mines 6..... 106
Canadian Occidental Petroleum Albert Mines 7..... 110
AtlanticRichfield Boudreau 1..... 115

Page

AtlanticRichfield Dover 1A..... 124
Canadian Occidental Petroleum
Rosevale..... 130
AtlanticRichfield Rosevale 1..... 135
AtlanticRichfield Urney 1..... 139

2. Core sample descriptions..... 141
AtlanticRichfield Albert Mines 1A..... 141
Canadian Occidental Petroleum
Albert Mines 2..... 142
Canadian Occidental Petroleum
Albert Mines 4..... 145
Canadian Occidental Petroleum
Albert Mines 5..... 147
Canadian Occidental Petroleum
Albert Mines 6..... 151
Canadian Occidental Petroleum
Albert Mines 7..... 154
AtlanticRichfield Boudreau 1..... 156
AtlanticRichfield Dover 1A..... 158
Canadian Occidental Petroleum
Rosevale..... 159
AtlanticRichfield Urney 1..... 161

3. X-ray diffraction results..... 162
AtlanticRichfield Albert Mines 1A..... 162
Canadian Occidental Petroleum
Albert Mines 2..... 162
Canadian Occidental Petroleum
Albert Mines 4..... 162
Canadian Occidental Petroleum
Albert Mines 5..... 162
Canadian Occidental Petroleum
Albert Mines 6..... 163
Canadian Occidental Petroleum
Albert Mines 7..... 164
AtlanticRichfield Boudreau 1..... 164
AtlanticRichfield Dover 1A..... 164
Canadian Occidental Petroleum
Rosevale..... 164
AtlanticRichfield Urney 1..... 165

4A. Fischer assay results..... 166
AtlanticRichfield Albert Mines 1A..... 166
Canadian Occidental Petroleum
Albert Mines 2..... 166
Canadian Occidental Petroleum
Albert Mines 4..... 166
Canadian Occidental Petroleum
Albert Mines 5..... 166

Page

Canadian Occidental Petroleum
Albert Mines 6..... 167
Canadian Occidental Petroleum
Albert Mines 7..... 168
AtlanticRichfield Boudreau 1..... 168
AtlanticRichfield Dover 1A..... 168
Canadian Occidental Petroleum
Rosevale..... 168
AtlanticRichfield Urney 1..... 169

4B. Rock-eval pyrolysis results..... 170
AtlanticRichfield Albert Mines 1A..... 170
Canadian Occidental Petroleum
Albert Mines 2..... 170
Canadian Occidental Petroleum
Albert Mines 4..... 170
Canadian Occidental Petroleum
Albert Mines 5..... 170
Canadian Occidental Petroleum
Albert Mines 6..... 171
Canadian Occidental Petroleum
Albert Mines 7..... 172
AtlanticRichfield Boudreau 1..... 172
AtlanticRichfield Dover 1A..... 172
Canadian Occidental Petroleum
Rosevale..... 172
AtlanticRichfield Urney 1..... 173

ABSTRACT

This report describes the stratigraphy, lithology, mineralogy, structure and organic geochemistry of portions of the Mississippian Albert Formation oil shales along the southeast margin of the Moncton subbasin, and is based on the detailed geology of 11 core hole sections with interpreted integration of adjacent surface data.

Oil shales are present as three distinct lithologies; laminated marlstone, clay marlstone and dolomite marlstone. Each lithotype has distinctive mineralogy, sedimentary structures and geochemical characteristics. Structural deformation is more pronounced in specific lithotypes.

The best known reserves are contained in the Albert Mines zone, dominantly laminated marlstones, with yields averaging 100 litres/tonne in the better areas. The prime deposit, at Albert Mines, contains an estimated 42.8×10^6 cubic metres (270 million barrels) in situ shale oil reserves in an area 2 km^2 to a depth of 600 metres.

OIL SHALES OF THE ALBERT FORMATION
NEW BRUNSWICK

INTRODUCTION

Oil shale deposits of the Albert Formation in the Moncton subbasin, New Brunswick (Fig. 1) are at this time the best studied of the known Canadian oil shale deposits (Macauley, 1981), and that at Albert Mines (Fig. 2) presently appears to be the most economically attractive. The Albert Mines deposit was recognized to require considerable additional geological study before any precise determination of shale oil potential could be made. A study, the results of which are contained in this report, was deemed essential to determine the most appropriate procedures for core evaluation and other exploration and development investigations. These findings will hopefully define a basic procedure to evaluate the oil shale potential of other deposits, both in the Albert Formation of New Brunswick, and elsewhere in Canada. Universally comparable data can thus be anticipated for all Canadian oil shale occurrences.

This study is based on the detailed descriptions of the lithology and structural attitudes of oil shale section penetrated by four holes cored by the AtlanticRichfield Company in 1968 and by seven holes cored by the Canadian Occidential Petroleum Company in 1976, all within the Moncton subbasin, Geologically selected samples of the cores were analyzed to provide data of both the inorganic and organic geochemistry of the Albert Formation. Analytical techniques utilized rock density determination, carbon analysis, Rock-eval pyrolysis, Fisher assay and X-ray diffraction. Although no detailed mapping

of bedrock geology was herein undertaken, available surface information has been incorporated into the interpretation.

Three distinct oil shale lithotypes (laminated marlstone, clay marlstone and dolomite marlstone) were recognized from the core data of the Albert Mines area. Based on these oil shale types, the Frederick Brook Member of the Albert Formation was then informally divided into an upper unit of clay marlstone, dolomite marlstone and shale, the Albert Mines zone of dominant laminated marlstone, a clay marlstone zone of clay marlstone and shale, and a basal dolomite marlstone section. Because the laminated marlstone lithology has the highest shale oil yields, averaging slightly less than 100 litres/tonne, the name "Albert Mines Zone" is here informally proposed for the economically most attractive unit within the total oil shale sequence. These units are tentatively correlated westerly to Rosevale and Urney, and easterly to Boudreau and Dover (Fig. 2) even though facies changes occur and the excellent laminated marlstones of Albert Mines are not significantly developed at these other areas.

Both primary sedimentary and imposed diastrophic structures were noted in the cores. Sedimentary features were utilized in the interpretation of the oil shale lithologic types, whereas the tectonic structures assisted in the estimations of depositional thickness which were significant to the four-fold zonation of the oil shale interval.

Mineralization variations in the distributional patterns of calcite, dolomite, clays, quartz and feldspar can all be related directly to the basic lithologic types. Although the shale oil yield is directly correlative to the kerogen content in virtually identical proportions throughout the oil shale interval, the kerogen content (by weight % organic carbon) does vary with the oil shale type. Sufficient understanding of the inorganic-organic mineralogy of the oil shales has been gained that geophysical downhole logs, especially the density

curve, can be considered as effective exploratory development tools.

ACKNOWLEDGEMENTS

Cores from the Canadian Occidental Petroleum Ltd. program were examined at the New Brunswick Department of Natural Resources field office at Sussex, New Brunswick, where A. A. Ruitenberg and S. R. McCutcheon were most helpful in the use of the facilities, and also provided field data from surface work by M. J. McLeod in the Albert Mines area. R. D. Howie, at the Atlantic Geoscience Center, Dartmouth, Nova Scotia, assisted in examination of the AtlanticRichfield Oil Company cores at that location. S. R. McCutcheon and R. D. Howie each provided tours of Albert Formation surface sections to the west in the Apohaqui-Sussex-Urney area and to the north on the Kingston Uplift in the Indian Mountain area. Although not sections of oil shale, knowledge of these surface data has been instrumental in the more local interpretations of this report, especially the indicated facies relationships. J. B. Hamilton, D. E. Gemmell, C. St. Peter and B. M. W. Carroll of the New Brunswick Department of Natural Resources and T. G. Powell of the Institute of Sedimentary and Petroleum Geology, Calgary have reviewed the manuscript.

At the Institute of Sedimentary and Petroleum Geology, Calgary, Alberta, T. G. Powell and L. R. Snowdon provided and supervised the X-ray diffraction studies. Assistance was also provided for interpretation results from these studies. Computer facilities of the Institute were also utilized to investigate inter-relationships of some of the analyzed factors.

D. E. Gemmell and T. G. Powell are thanked for their aid, interest and encouragement rendered during the completion of the project. Funding for the study was from two sources. The contract with F. D. Ball, Fredericton, New Brunswick, and the costs of some geochemical investigations conducted by Core Laboratories Ltd., at Aurora, Colorado, and at Dallas, Texas,

were funded under the Mineral and Fuels Subagreement of the General Development Agreement between the Province of New Brunswick and the Federal Department of Regional Economic Expansion. The Geological Survey of Canada, through the Institute of Sedimentary and Petroleum Geology, Calgary, Alberta, provided the contract under which G. Macauley, Calgary, Alberta, participated in the study.

STRATIGRAPHY

The Carboniferous rocks of New Brunswick rest with pronounced angular unconformity on a basement of pre-Middle Devonian and Precambrian rocks deformed by the late Lower Devonian Acadian Orogeny. The deformed rocks are intruded by numerous Acadian granitoid plutons. Locally the pre-Carboniferous basement consists of post-Acadian Upper Devonian rocks. The pre-Carboniferous Paleozoic metasediments consist of cyrstalline limestones, slates, arkosic sandstones and quartzites whereas the Precambrian section consists of gneiss, schist, quartzite, slate and greenstone.

Carboniferous sediments of the Atlantic Provinces consist dominantly of terrestial clastics deposited in a series of connected intermontain basins within the regionally subsiding Fundy (Successor) Basin (Fig. 1). With the exception of local unconformities, and a late Lower Carboniferous marine incursion, deposition continued in one or other parts of the basin into the Permian. Throughout this period, the roles of various areas as either that of a positive source of detritus or that of a depositional sub-basin shifted with the result that those areas that had been previously positive became depositional basins. Carboniferous marine incursion was followed by the late Lower Carboniferous epeirogenic uplift, resulting in renewed non-marine clastic sedimentation which continued into the Permian.

Carboniferous tectonic activity is defined as the Maritime Disturbance. Although evidence of the disturbance is minimal on the New Brunswick Platform, the effect in the Fundy Basin is evident by local unconformities, by folding, and by both reverse and strike-slip faulting.

The presence of only one marine incursion has made lithologic subdivision and subsequent stratigraphic correlations

difficult. This problem has plagued every individual involved in the Carboniferous of Atlantic Canada. Virtually every publication is accompanied by a table of formations which place that worker's stratigraphic interpretation into the context of the many previous publications, all of which vary to some degree. As this study deals only with the early Lower Carboniferous Albert Formation of the Horton Group within the Moncton sub-Basin (Fig. 2), the problem should have been reduced in scope, but has remained somewhat difficult because of additional facies interpretations.

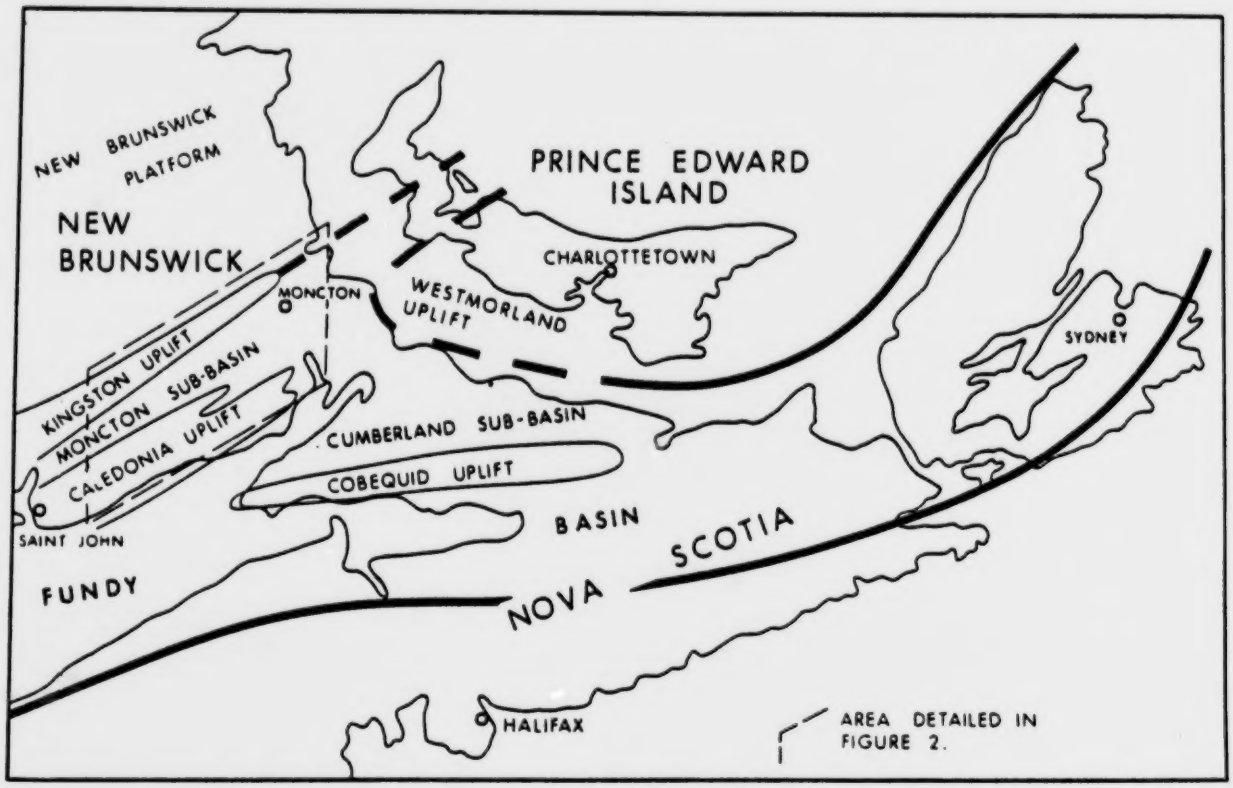


Figure 1: Tectonic elements of the Fundy Basin, New Brunswick-Nova Scotia

The Horton Group consists of a predominantly grey sequence, the Albert Formation, deposited between two red bed sequences, the underlying Memramcook Formation and the overlying

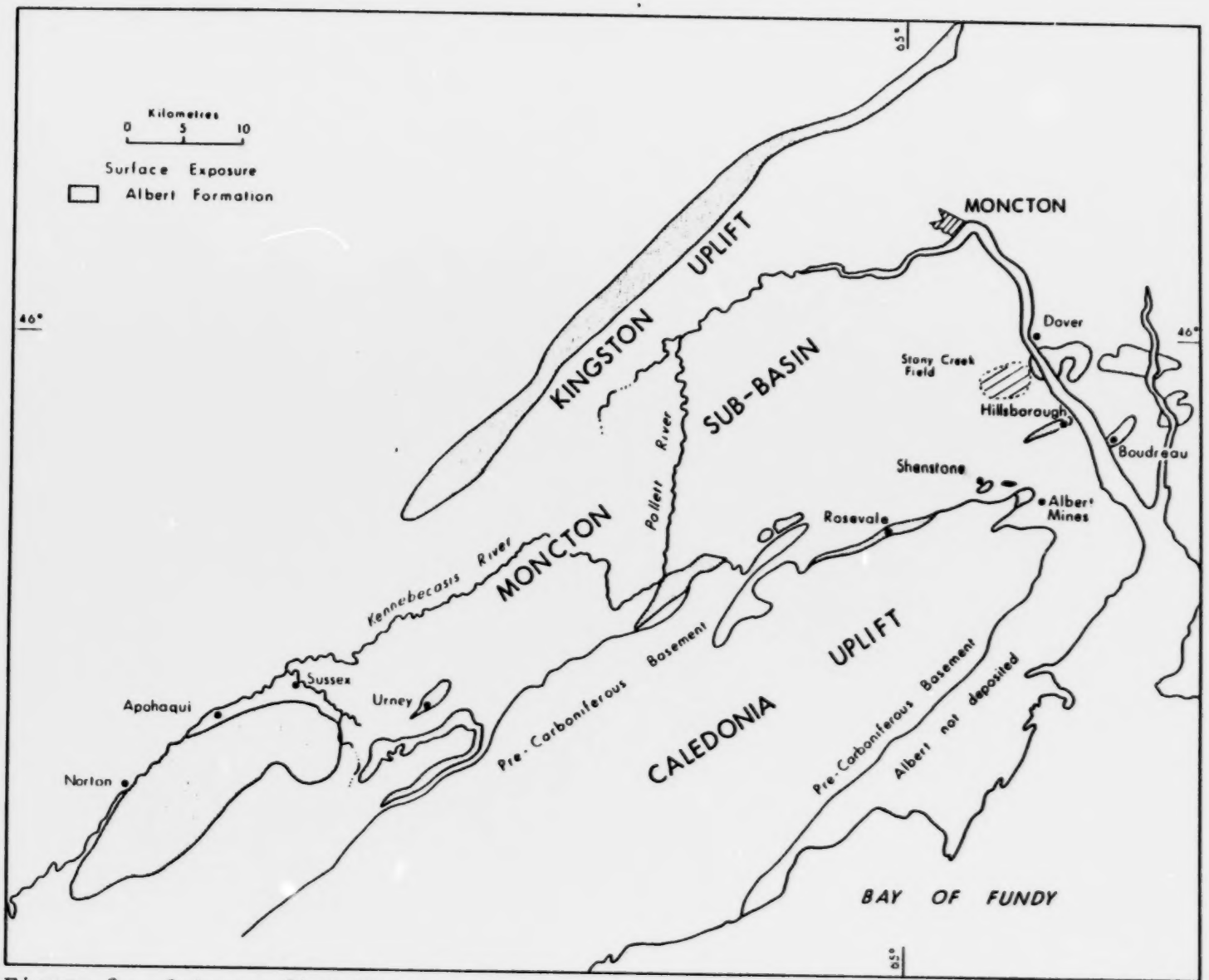


Figure 2: Outcrop distribution Albert Fm., Moncton sub-Basin-Kingston Uplift, N.B.

Moncton Group (Hillsborough and Weldon Formations) as defined by Gussow (1953).

The Memramcook Formation is composed of conglomerate, sandstone, siltstone and shale, commonly red, often distinctively purplish-red, and with green intervals. The upper contact is generally conformable with, and gradational to, the overlying Albert Formation although local disconformities are suspected. Because of the interlensing of the colour types, the contact has been arbitrarily placed where either red or grey colouration becomes dominant. Hacquebard (1972) indicated a late Devonian age [Famennian (Barss *et al.*, 1979)] on the basis of miospores.

The Moncton Group can be divided locally into the Weldon Formation, which consists predominantly of red mudstones, shales, siltstones and sandstones, and the Hillsborough Formation consisting of coarser grained red conglomerates. In places there is a transition of grain size from fine to coarse upward, representing a conformable sequence: at these localities, the Moncton Group is not subdivided. Elsewhere, the lower finer grained Weldon units are eroded and structurally contorted below Hillsborough conglomerates. Hacquebard (1972) indicated an early Carboniferous age (Viséan) for the Moncton Group. Although Gussow included the Weldon Formation in the Horton Group and the Hillsborough Formation in the Windsor Group, recent workers (McLeod, 1980 and McCutcheon, 1981) have removed both formations from the respective groups. Similar to differentiation of the Memramcook and Albert Formations, the contact between the Albert Formation and the Moncton Group must be arbitrarily assigned by colour dominance.

The intermediate grey coloured shale sequence, the Albert Formation, was proposed by Hayes (1927) and formally defined by Norman (1932). The sequence consists of siltstones, sandstones and shales, portions of which are dolomitic and/or calcareous, conglomerates, limestones, dolomites and kerogeneous

dolomitic marlstones (oil shale). A localized evaporite sequence, the Gautreau evaporite, occurs in the uppermost part of the formation. The age of the Albert ranges from possibly Late Devonian (Famennian) through Tournaisian to possible Viséan (essentially Lower Mississippian) (Pickerill and Carter, 1980).

The original stratigraphic nomenclatural scheme proposed to describe the stratigraphy of the Albert Formation was based on the recognition of six oil and gas bearing zones, the "driller sands" recognized during the early development of the Stoney Creek oilfield. The upper Albert Formation was divided into four sandstone-bearing intervals (Zones I-IV), overlying the interval of dominant oil shale (Zone V), with sandstone (Zone VI) at the base. Although attempts have been made to utilize this scheme beyond the limits of the Stoney Creek field, the rapid lateral facies changes make its application to the Albert Formation throughout the Moncton subbasin tenuous at best.

Greiner (1962) proposed a three-fold subdivision of the Albert Formation (Fig. 3), to include a lower unit of sandstone, siltstone, shale and conglomerate, the Dawson Settlement Member, the medial Frederick Brook Member consisting of oil shale, limestone, calcareous shale and siltstone, and the uppermost Hiram Brook Member of siltstone, shale, calcareous sandstone and minor oil shale. The local salt-bearing zone, the Gautreau evaporite, occurs within the Hiram Brook Member. Although the Dawson Settlement Member includes a little or no oil shales or argillaceous limestones, differentiation of Dawson Settlement from the Hiram Brook Member would be very difficult if the distinctive medial Frederick Brook Member were not present.

More recent data indicate that coarser grained clastics are more widespread within the Albert Formation than had initially been suspected. The Can. Oxy. Albert Mines 7 (Fig. 4) and AtlanticRichfield Boudreau 1 (Fig. 5) core holes encountered grey polymictic conglomerates inter-zoned with all members of the

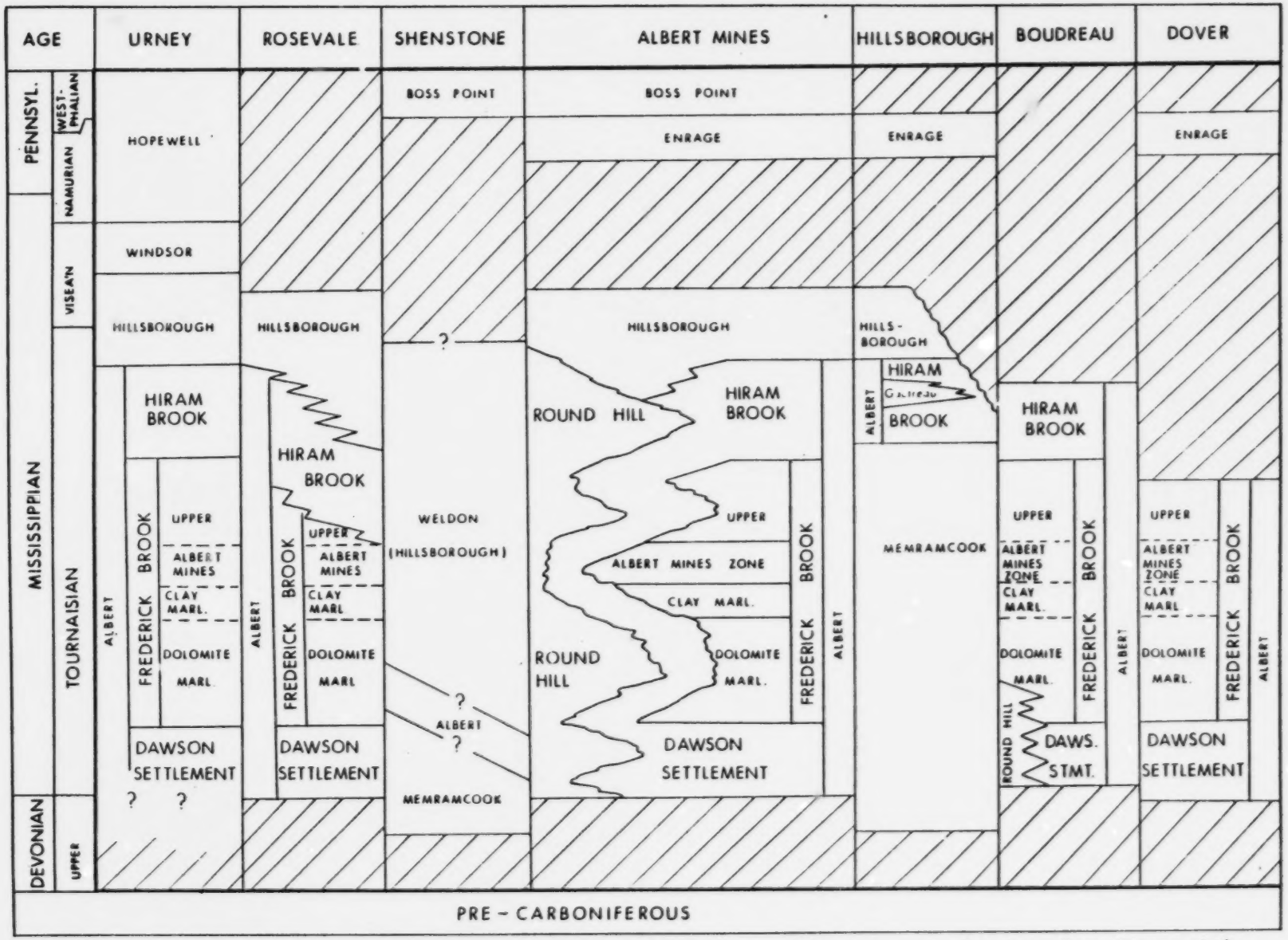


Figure 3: Carboniferous nomenclature and correlations, Moncton sub-Basin, New Brunswick

Albert Formation. These beds correspond to the Round Hill Formation fanglomerate mapped and proposed by McLeod (1980).

Worth and Crosby (1975) noted the presence of red conglomerate above a thin zone (60m/200') of grey shale overlying red beds in well cuttings from New Brunswick Oilfields #151, just northwest of the Albert Mines area near Shenstone (Fig. 2). This sequence was recently confirmed by the Can. Oxy. Shenstone 1 core hole (Canadian Occidental Petroleum Ltd., personal communication, 1982) a nearby offset to the New Brunswick Oilfields #151 location. Such sequences have been attributed to erosion of the Albert beds below the Moncton Group; however, there is evidence that the Moncton Group must be considered, at least locally, as the lateral equivalent of, as well as overlying, the Albert Formation.

In an internal report, Imperial Oil Company (1960) described a normal uppermost Albert section, including Gautreau salt, overlying a thick (636.7m/2089') clastic red bed sequence in the stratigraphic position of the Frederick Brook and Dawson Settlement Members at Imperial Hillsborough 1, near the town of Hillsborough (Fig. 2). The report interpreted the Albert Formation grey beds to change abruptly in facies to the red bed sequence.

On Figure 3, the generalized correlation chart, the red bed sequences encountered at Shenstone and Hillsborough are illustrated as lateral equivalents of the Albert grey beds.

Thickness variations of the Albert Formation appear to be as much as, or more than, due to facies change than to erosion or to varying rates of subsidence across the sub-basin. Similar facies relationships are also projected for the three members within the Albert Formation. The generalized correlation diagram (Fig. 3) attempts to illustrate both the nomenclature and facies relationships of the continental terrestrial clast-

sequence within which the oil shales were deposited. More specific lithologic data and interpretative correlations are illustrated on the core hole logs and specific site interpretations. These figures incorporate the detailed descriptions of the lithology and structural attitudes of the rock penetrated by the core holes (Fig. 4 and 5) as well as previously completed bedrock mapping of the respective areas. Illustrative cross-sections have been prepared for the Albert Mines, Boudreau, Dover, Rosevale and Urney areas (Fig. 15, 17, 18, 19 and 20).

The three-fold nomenclature scheme, proposed by Greiner (1962) to subdivide the Albert Formation, has been maintained with the addition of a further division of the Frederick Brook Member into four zones. The Round Hill conglomerates are recognized to be laterally equivalent to the Albert Formation. The point to be made and kept in mind is the relationships of the members of the Albert Formation, and indeed of the relationships between the Albert Formation and its bounding rock units, are those of facies change. Colour variations are still important to understanding and mapping these relationships; however, based upon the data of this and other studies the red versus grey relationship must be utilized with caution, given the known oxidation/reduction reaction complications, to define sub-aerial versus sub-aqueous depositional environments rather than just a layered stratigraphic sequence.

The Frederick Brook Member has been subdivided into four lithologic units, the three lower units having been named the dolomite marlstone, the clay marlstone and the Albert Mines zones, in ascending order. They consist predominantly of dolomite marlstone, clay marlstone and laminated marlstone (dolomite-clay-kerogen) respectively. An upper unnamed unit consists predominantly of shale, dolostone, and dolomite marlstone, Recognition of this four-fold subdivision of the Frederick Brook Member rests primarily upon the distinction of the clay marlstone zone with its increasing clay content and

associated relatively high water content as indicated by Fischer assay results. In the areas such as Albert Mines, recognition of the Albert Mines zone is assured by the high kerogen content; however, such recognition is not nearly so positive in areas were environmental conditions were not favourable to the concentrated accumulation of algae material.

Oil shales may occur through most of the Albert Formation, as reported for the Stoney Creek Field area (Howie, 1980), and as logged in the Hiram Brook Member in Atlantic-Richfield Rosevale 1 (Fig. 5). These uppermost oil shale zones of the Hiram Brook Member are thin and sporadic. Not constituting a significant oil shale sequence, such oil shale beds are left as a secondary lithology within the Hiram Brook Member.

Conglomerates of the Round Hill Formation are not continuous but are recognized to be discontinuously inter-tongued with all three members of the Albert Formation (Fig. 3). The Round Hill is a prime example of the difficulties of nomenclature in continental clastic sequences where facies change so rapidly. Used to denote a conglomerate facies, the Round Hill is herein treated as a member of the Albert Formation, recognizing that this facies occurs throughout the Albert Formation, and is in part the sub-aqueous facies equivalent of the Moncton Group and Memramcook Formation red conglomerates.

LITHOLOGY

Three marlstone lithotypes form the oil shale deposits of the Albert Formation. The three, dolomite marlstone, laminated marlstone and clay marlstone, are interlaminated, interbedded and intergradational (Plates 1 and 2). They are defined by variations of their three major components, dolomite (locally calcite and minor siderite), clay (mostly montmorillonite-illite), and organic kerogen (Plate 3). In addition, quartz and feldspar modify the three primary lithotypes, in particular the dolomite marlstone. Sandstones and conglomerates are present within the oil shale sequence, but do not constitute oil shale deposits in themselves, even though low porosities are often impregnated by bitumen and/or kerogen. The physical characteristics of the oil shales are dependent upon the physical characteristics and relative abundance of their components with the result that colour, density, fissility, hardness and resistance to weathering vary widely. Although the Albert Formation can be divided into members and lithologic zones, the lithotypes of these units, and in particular the subdivisions of the Frederick Brook Member, tend to be markedly intergradational.

Dolomite Marlstone

The dolomite marlstone, as used herein (Plates 1.c and 3.e), is a composite unit and includes the massive dolomitic marlstone and low-grade sandy marlstone of King (1963). King described the massive dolomitic marlstone as a mixture of detrital grains, ooze and organic matter in beds more thickly developed than other lithologic types. A portion of the ooze consists of dolomitic spherical bodies filled with reddish-brown coloured organic matter. King's low-grade sandy marlstone was described as thin beds of detrital quartz and feldspar in a disorganized matrix of dolomite ooze and organic matter,

interbedded with thin layers of clay-organic complex, the organic matter having a reddish tinge.

Kerogen content of the dolomite marlstone is recognizable by colour variations as the natural lighter brown of the dolomite darkens with increasing organic content. Kerogen may be finely disseminated through the massive dolostone (Plates 1.e and 3.a) but predominantly occurs as dark brown kerogen laminae (Plates 1.a and 3.c), generally flat-lying to slightly wavy. Such waviness may result from irregular depositional quantity or from irregularity of depositional surface. Laminations may increase to the point of being "waved" (Plate 1.b) but such quantity of kerogen is uncommon to this lithology. In sections of lesser kerogen content, the laminae may be discontinuous across the core, being present only as irregular parallel flecks. Many pseudonodule sedimentary pressure solution structures (Plate 1.f) occur in this high dolomite, low kerogen interval. In addition, rip-up breccias (Plates 1.e and 3.b) are common to intervals almost barren of kerogen.

Sand and silt content vary greatly, from virtually none to 40% of the rock and in many places the marlstone grades to barren shale, siltstone and sandstone beds. Where dolomite remains the matrix mineral, the sand and silt beds are massive, but where grain support sandstones and siltstones are present, the zones may inter-grade and interbed. Sedimentary sills and dikes occur within these intervals.

Laminated Marlstone

The highest kerogen content and commensurate greatest shale oil yields are present in the laminated marlstones of the Albert Mines Zone. This lithologic unit is King's (1963) "blocky laminated marlstones".

The laminations arise from alternating kerogen and carbonate (dolomite and calcite), ranging from 30% to 40% of each, and imparting a varved light-dark appearance (Plates 2.b and c). Kerogen laminae are resistant to weathering and retain their condition, even though finely laminated and fissile. The binding and protective effect of the kerogen increases with content so that the most pervasively laminated marlstones were described as "blocky" by King (1963); these marlstones are, however, easily split along the bedding planes to produce thin sheets of the oil shale.

Within the Albert Mines zone, laminated beds may grade to dolomite marlstone by an increase of the dolomite content, or to clay marlstone by an influx of clay. In either case, increased dolomite or clay is at the expense of the kerogen content with the result that shale oil yields decrease. Although lenses of sandstone and siltstone are present, the occurrence of these rock types and of high sand and silt contents in the marlstones is insignificant in comparison to that of the dolomite marlstones.

The laminations, acting as planes of structural weakness, and the kerogen, acting as promotional agent, have made the laminated marlstones most susceptible to structural deformation. The numerous microfolds, faults and slickensided surfaces associated with this lithology appear to be tectonically induced (Plates 2.a, c, d, e and 3.f), in contrast to structures noted associated with the dolomite marlstones which are interpreted to be of sedimentary origin (Plates 1.d, e, f and 2.d).

Clay Marlstone

The clay marlstones are greyish-brown to brown in colour, generally browner with increasing kerogen content and are dolomitic and laminated. Clay is the significant mineral

component, although dolomite and kerogen content may increase sufficiently so that zones of laminated and/or dolomite marlstone occur within the shale interval (Plates 1.a, 2.b and 3.d). Clay content may also increase to create organically deficient grey shales. They are typically accompanied by a marked decrease in dolomite content. Such shales may remain laminated and fissile, or may grade to more massive claystone intervals.

The clay marlstones are less varved than the laminated variety because of decreased organic laminae. The corresponding increase in clay, accompanied by chemical and/or mechanical weathering, results in a marked degeneration into thin paper-like sheets (i.e. "papery shales", King, 1963). Weathering resulted in almost complete disintegration of non-organic grey shale beds.

Virtually all the structures encountered, associated with the clay marlstones, are considered to be tectonically induced (Plate 2.f). Due to the lesser dolomite content, the micro-faults, drag folds, convolute contortions and ptygmatic folds are less evident in contrast to the laminated marlstones. Brecciation and slickensides, also common to the laminated marlstones, are prevalent in the clay marlstones where kerogen content is elevated.

In contrast to the non-organic claystone and grey fissile shales, a second shale type has been recognized below the dolomite marlstones at the base of the oil shale section. These lower shales are commonly brown in colour, massive and dolomitic, but yield virtually no shale oil, even though the brown colouration suggests organic content is present. The massive character and dolomitic content indicate the affinity of this shale type to the dolomite marlstones. In contrast, the younger uppermost grey shales are comparable with the laminated marlstones. Structural deformation is not common to these lower shales.

Summary

The oil shales in the Albert Mines area are informally divided into four units. The uppermost unit comprises grey claystones and shales that grade into fissile, laminated, organic, slightly dolomitic, brownish shales. The latter grade downward into a second unit of dark brown to tan, finely waved, kerogen-bearing, laminated marlstones of the Albert Mines zone. The high kerogen marlstones of the Albert Mines zone transitionally merge with an underlying third unit of laminated organic clay marlstones. Both marlstones exhibit considerable structural deformation; brecciation and slickensiding in the clay type, and drag folding, convolute contortions, faulting and over-turning in the laminated marlstone.

Beneath the clay marlstone beds is a fourth unit of dolomite marlstones, generally brown in colour, massive to laminated depending upon kerogen content, and exhibiting sedimentary depositional structures in contrast to the tectonic features of the overlying laminated and clay marlstones. Quartz and feldspar grains, although present to a minor degree in the overlying oil shale lithologies, become a significant part of the dolomite marlstone unit, with intervals tending to dolomitic siltstones and minor amounts of sandstone.

Underlying the dolostone oil shales is a sequence of brown dolomitic massive shale (claystone) and brown dolomitic argillaceous siltstones.

This sequence of oil shale deposition is generalized from the section encountered in the Albert Mines area. East-west facies variations will be described more fully under the interpretations of other specific sites.

MINERALOGY

In North America, oil shales are still regarded primarily as a source of petroleum products; however, European experience indicates a much broader scope for ulitization of such deposits. At the Estonian operation in the Baltic Basin, not only are petroleum products and electricity generated as energy forms, the shale ash provides the raw material for road base, lime and sand bricks, lime fertilizer and cement (Öpik and Kaganovitch, 1981). At the Rohrback Zementwork, Dotterhausen, Germany, oil shale is burned in a fluidized bed to produce electricity and residue used to produce cement and mortar binder, a dual function for the oil shale (Schmitz, 1981). The potential multi-role function necessitates a full knowledge and understanding of the mineralogy of any oil shale deposit.

Two factors complicate determination of mineral components. Kerogen virtually surrounds most of the grains, inhibiting the acid reaction by which carbonate can be recognized: most samples remain almost inert in cold or hot 10% HCl solution. Detection of the harder quartz and feldspar detrital grains by scratching is also inhibited by the kerogen film. Much of the quartz-feldspar component is in the size range 20-60 microns (King, 1963), not discernible by normal visual inspection, including reflecting stereo-microscope examination. These problems are evident in the core and sample descriptions (Appendices 1 and 2) where mineral identification of both carbonates and terrigenous clastics have not been recorded. To obtain as much mineralogical data as possible, all samples acquired for geochemical investigation were also subjected to X-ray diffraction analysis.

Individual samples are denoted by core hole name, sample number and depth in metres. The sample numbers correspond to those along the right hand edge of the lithologic-geochemical

log presentations (Fig. 4 and 5). The indicated zones refer to the lithologic units of the Albert Formation, including the Hiram Brook facies (HB), upper shale zone (US), Albert Mines zone (AM), the clay marlstone (CM) and dolomite marlstone (DM) units, and the Dawson Settlement (DS) and Round Hill (RH) facies.

Semi-quantitative results were obtained from diffraction peak heights and are reported in bar graph form (Figs. 6a, 6b and 6c) and as actual calculated percentages (Appendix 3). These computations represent relative rather than absolute values. Because of varying crystal shapes and sizes, quartz tends to be over-estimated whereas clays are recorded at less than true content, making no allowance for kerogen, which may be up to 40% of the rock material; consequently, most of the true contents for specific minerals will probably be somewhat less than indicated. This is not considered to be significant as the interpretations are herein based primarily on the relative changes in specific mineral content.

Several pronounced mineralogical relationships and compositional trends are strongly indicated from the limited number of samples analyzed: considerably greater sample control will be required to develop these concepts to their full potential of zonal and environmental recognition and correlation.

The carbonate minerals dolomite, calcite and siderite, terrigenous derived quartz, feldspar and clays, as well as clays and quartz from decomposition of feldspar, and the alteration zeolite analcime (from clays), comprise virtually the entire inorganic component. Each of these minerals is contained within distinct distributional patterns in the Albert Mines area: most of these patterns appear regionally applicable to other oil shale areas.

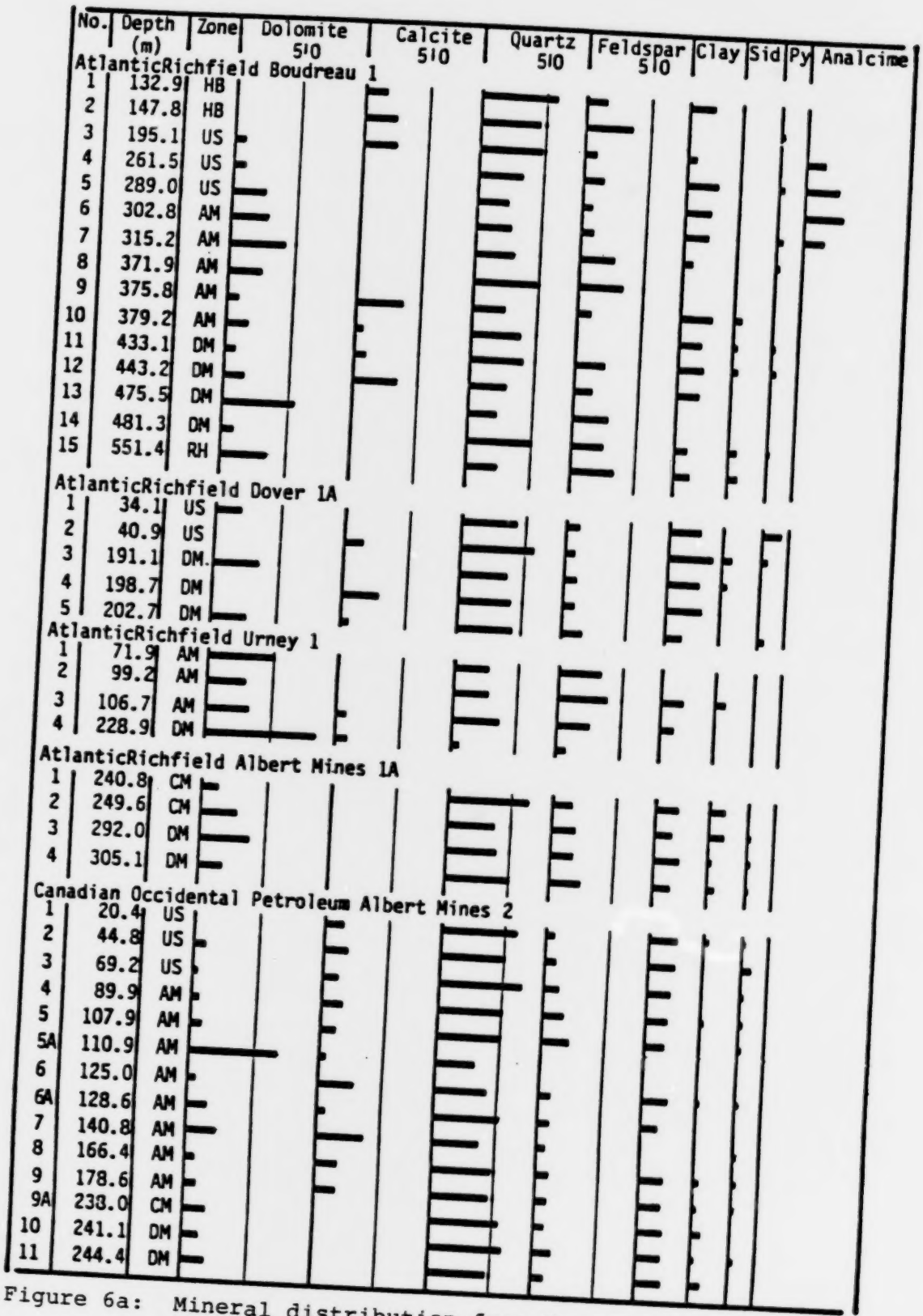


Figure 6a: Mineral distribution from X-ray diffraction analyses for Boudreau, Dover, Urney, Albert Mines

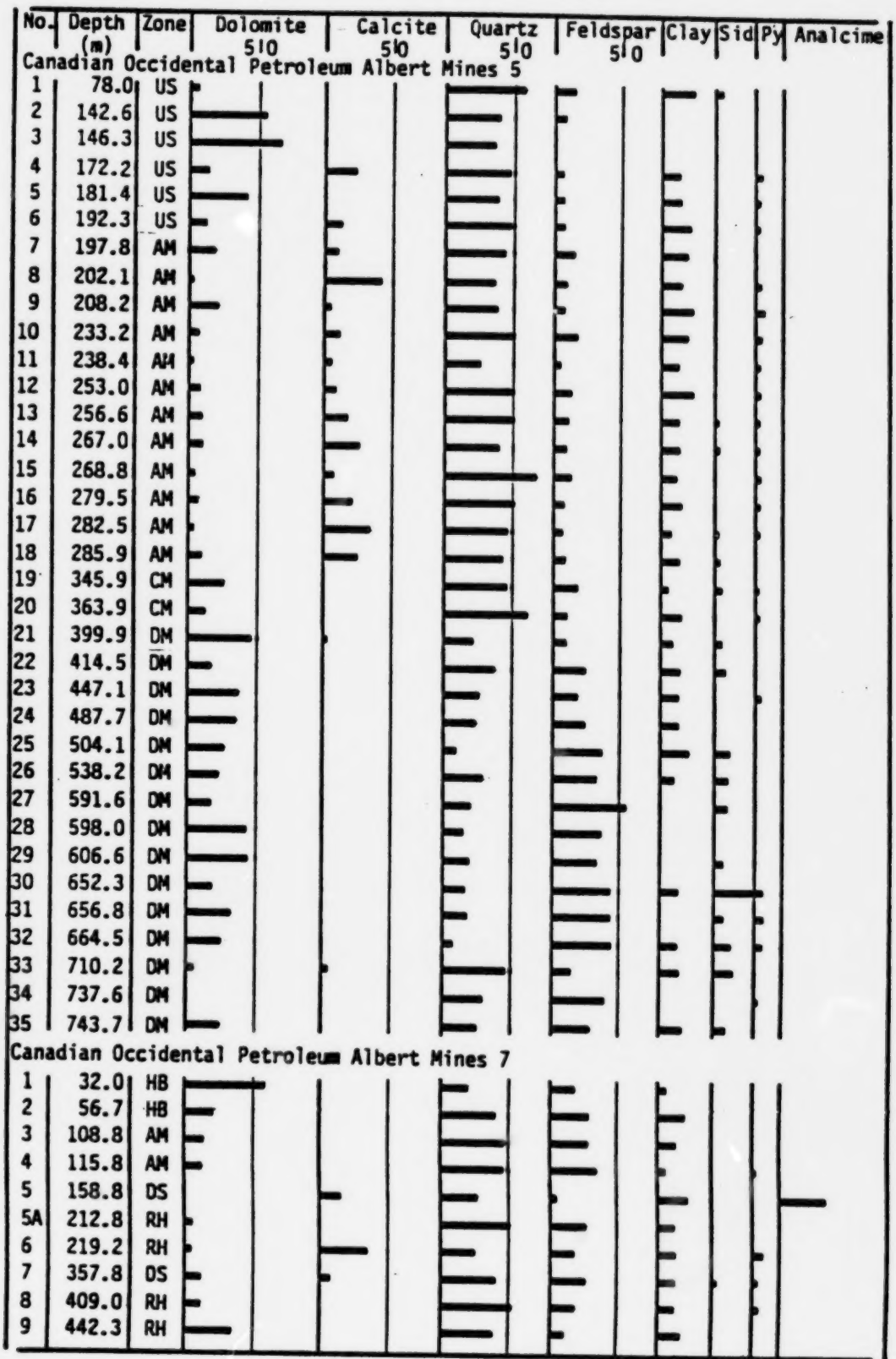


Figure 6b: Mineral distribution from X-ray diffraction analyses for Albert Mines

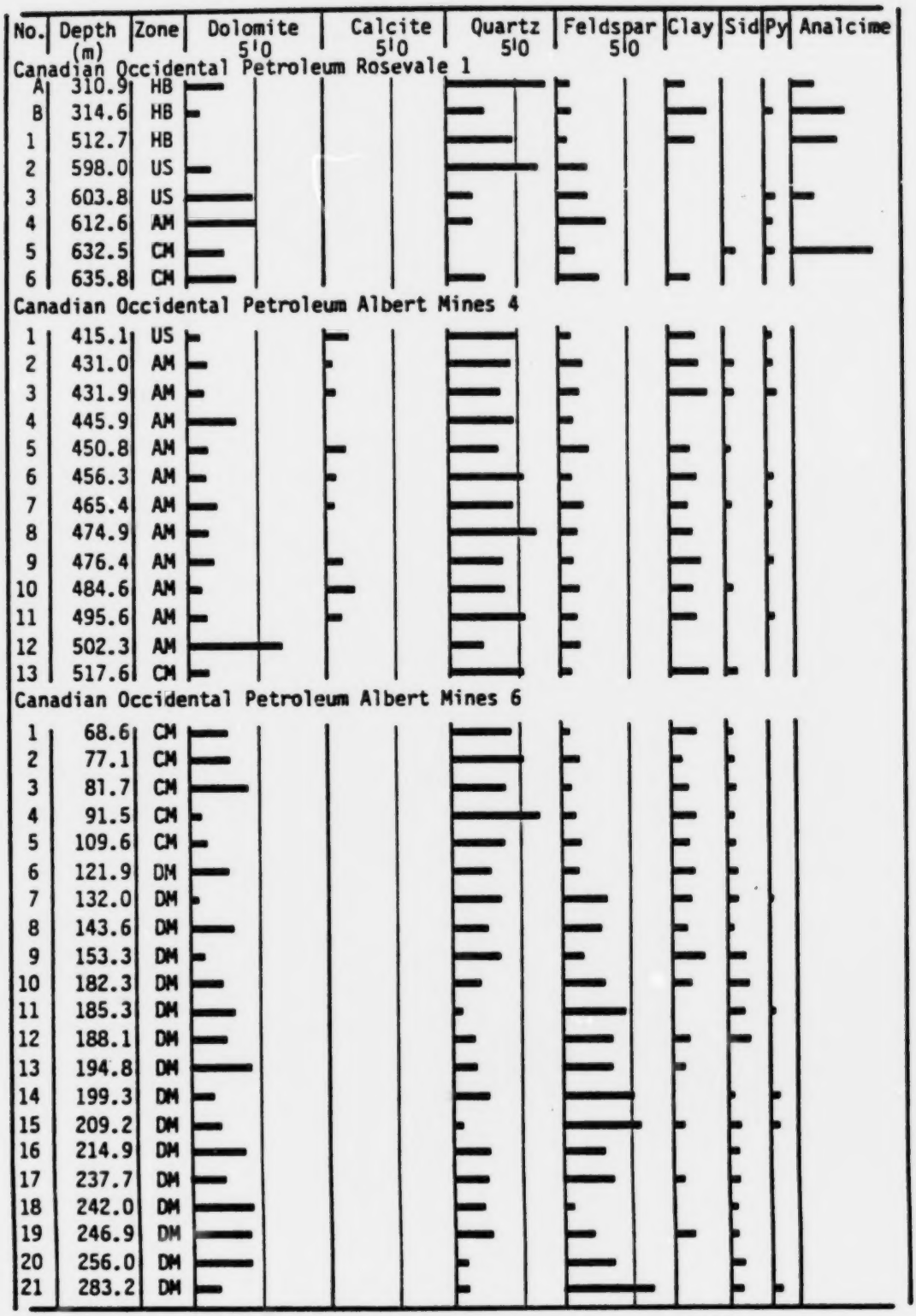


Figure 6c: Mineral distribution from X-ray diffraction analyses for Albert Mines, Rosevale

Dolomite

The general distribution of dolomite has already been defined by the lithologic subdivision of the Albert Mines area, whereby dolomite increases downward into the dolomite marlstone zone. Calculated X-ray diffraction percentage values in the Albert Mines zone are almost as high as those of the lower unit, but, after allowing for downward decrease in kerogen, the net dolomite, which increases at the expense of kerogen and clay, is much greater in the dolomite marlstone zone.

Calcite

The almost complete absence of calcite in samples below the Albert Mines zone in the Albert Mines area inversely relates to the dolomite distribution. Calcite-rich laminae are present in the Albert Mines and upper zones as well as calcite-filled fractures. This presence of calcite was possibly controlled by a minor change in conditions at the sediment-water interface whereby dolomitization was reduced upward in the section.

Although minor limestone zones were noted in the clay marlstone zone at Can. Oxy. Albert Mines 5 and within Round Hill facies at Can. Oxy. Albert Mines 7 (Fig. 4), significant calcite and limestone beds appear to be contained primarily within the Albert Mines zone and younger section.

Siderite

Although found only in small quantities, but present throughout all the sampled zones, siderite content increases downward in the section, reaching a maximum in the dolomite marlstone zone, thus correlating directly to dolomite in

distributional pattern.

Quartz-Feldspar

Within the upper zone, the Albert Mines zone, and the clay marlstone zone, quartz predominates over feldspar in quantity, whereas the reverse relationship, feldspar dominant, is distinctive to the dolomite marlstone zone. Where feldspar is less than approximately 20% of the inorganic component, several forms appear to be present: above this value, albite predominates.

The reversing quartz-feldspar ratio is not indicative of changing source material, but results from the inhibition of diagenetic alterations of the feldspars under the carbonate-depositing environments of the dolomite marlstone zone (Berkeland, 1974). Decreased clay and quartz resulted as feldspar remained unweathered in contrast to their decomposition in the overlying zones.

Within the uppermost oil shale zones, quartz and feldspar occur in very fine silt size grains (20 to a maximum 60 microns) indicating that much of the quartz is a probable weathering product of the feldspar. In the dolomite marlstone zone, especially the lower beds of that section, coarser silt to sand size quartz grains are definite terrigenous detritus.

Clays

Also linked to the distributional trends of the dolomite and quartz-feldspar is a reduction of the clay content downward into the dolomite marlstone zone. The greater clay content above the dolomite marlstone zone is likely due to the combination of diagenetic alteration of the feldspar and an

increased influx of detrital clay.

Mixed larger clays (montmorillonite) and illite are present throughout, generally with the mixed clays more common, and with a suspected relative increase in illite in the dolomite marlstone zone. Kaolin appears to be only sporadically present from the limited data of this study.

The reduced clay content of the dolomite marlstone zone was anticipated from plots of the water recovery data of the Fischer assays (Figs. 4 and 5). An increased water yield of the clay marlstone zone, the "shaliest" oil shale zone was the basis of initial zonal definition as the water was postulated to be derived from the clay minerals. This appears to have been a correct assumption from the X-ray diffraction results and from the results of the recent Fischer assays, where water yields virtually duplicate those conducted by AtlanticRichfield and Can. Oxy. in 1968 and 1976. This duplication infers the water to be mineral content, not related to pore and fracture filling or near surface ground waters.

Analcime

The zeolite, analcime, was located in several cores within the upper zone, Albert Mines zone and clay marlstone zone. It is missing from the dolomite marlstone zone and is generally present in zones of low feldspar content.

Although primarily a groundmass mineral of alkali-rich basic igneous rocks, analcime is also an alteration product of alkaline waters, rich in sodium, in volcanic ash and clay minerals. This zeolite was formed by such reaction in the Green River oil shales of the central western United States (Berry and Mason, 1959) and may also here result from alteration of the clay minerals of the Albert oil shales. The absence of analcime from the

dolostone and dolomite marlstone beds correlates directly to the reduced clay content of those lithotypes.

Others

The sporadic presence of pyrite is not surprising as the association between organic matter and pyrite is well documented. Iron and sulphur are present in most depositional environments and under reducing conditions, as would be expected in a lacustrine setting, ferrous iron, hydrogen sulphide and sulphur would react to produce iron sulphides.

Beta-quartz, a high temperature form, occurs irregularly in almost all zones and all core samples. Because no distributional pattern is evident, no significance can be projected for the occurrence of this mineral. Amphibole and apatite are accessory heavy minerals and gypsum is probably of diagenetic origin.

In summary, the quantitative distribution of quartz, clay, calcite and analcime defines a mutually related mineral group, which contrasts inversely to a second mutual group, dolomite, siderite and albite feldspar. These groups are not exclusive of each other but are each dominant to specific lithologic types. The quartz-clay-calcite-analcime group typifies the upper zone shales, the laminated marlstones of the Albert Mines zone and the clay marlstone, whereas dolomite-siderite-feldspar identifies the dolomite marlstone and dolostones. These groupings are not reflective of variable source material, but are controlled primarily by the geochemistry of the depositing environments. Although both are indicative of the upper zones, calcite and analcime do not co-exist in any significant amounts.

Whether or not these mineralogical variations will be

significant on a regional basis over the Moncton subbasin is conjectural from the scope of this study; however, two positive notes may here be interjected. During the general examination of the surface sections to the west in the Sussex and Apohaqui areas, the cementing material of Hiram Brook sandstones was noted to be calcareous in upper intervals and siliceous in the lower section, similar to the calcite distribution of the Albert Mines oil shales.

On the north-northwesterly flank of the Moncton subbasin, much of the section of the Albert Formation along the Kingston Uplift (Fig. 2) has variably been described as shale, dolostone and marlstone. Two spot samples, not oil shales, were collected. An upper sample, dark grey laminated shale, contains high quartz, lower feldspar and analcime, whereas a lower sample, dark grey massive hard marlstone, has increased dolomite, lower quartz and significant albite (Appendix 3). These spot samples indicate that the indicated mineralogic zonation may be significant over much of the basinal area.

STRUCTURES

The oil shale cores display numerous primary sedimentary and imposed diastrophic features. Some difficulty was encountered in recognizing bedding plane structures. The limited area available to examine bedding within cores placed some restrictions upon the observers, as did the physical degeneration of frequently large intervals of core because of inadequate storage.

Primary Sedimentary Structures

Stratification is the primary sedimentary structure of the oil shale intervals. Bedding thickness varies widely, from over a metre in thickly bedded strata of the massive dolostones and dolomite marlstones (Plate 1.c) to less than a millimetre in thinly varved strata of the laminated marlstones (Plate 2.b). Graded bedding and irregular stratification are commonly associated with the regular stratification. The vast majority of the bedding and laminations noted are planar: examples of irregular stratification are generally the result of penecontemporaneous deformation. The quiescent anoxic environment of deposition for the marlstones and dolostones would not produce the sediment movement required to create dynamic sedimentary structures.

Bedding plane lamination is the only depositional structure of the laminated and clay marlstones. Even the interbedded dolomite marlstones and local dolostone bed within the Albert Mines zone exhibit only lamination, being barren of penecontemporaneous deformation features. Within the optimum oil shale zones, the light-dark carbonate-kerogen varves are a striking feature of the deposits.

Penecontemporaneous deformation structures (Plates 1.d, e and f) are most evident in the dolomite marlstones and dolostones, where the finer lamination becomes much less evident. All are common to shallow water carbonate sedimentation, and include load features (particularly pseudonodules), pressure solution, slump, brecciation (rip-up clasts), convolute lamination, and sedimentary sills and dikes.

Within the lowermost sections of the dolomite marlstone zone, especially where increased clastic influx is noted, the interbedding of sediments of contrasting densities, the heavier silts and fine-grained sands and the lighter dolomites, organics and clays, has resulted in the optimum conditions for the generation of load structures. Most significant are pseudonodules, "fingers" of marlstone extending up into beds of silts or sands to varying degrees, and in some cases enclosing distorted fragments of silt or sand in marlstone.

A second nodular effect is present where pressure solution during lithification has concentrated kerogen, and possibly clay, into irregular laminae encasing irregular patches to distinct nodular forms of unaltered carbonate sediment, commonly described as "boudinage" structure.

Pre-lithification slump structures may indicate the presence of a slight paleoslope, at least locally. Such structures can be developed on slopes as low as 4 degrees (Morgenstern, 1967).

Soft sediment brecciation, better described as "rip-up" breccia, was noted at interfaces of fine sandstone lenses overlying dolostone and/or dolomite marlstone, as well as internally within dolostone beds wherein the dolostone clasts are virtually the same composition as the enclosing matrix. Both occurrences are indicative of shallow water deposition with sporadic rougher and/or faster moving bottom water conditions.

Convoluted laminae occur in the better laminated parts of the dolomite marlstones and are bracketed by planar bedding. Internally, the beds display complex patterns of folding including anticlines and synclines on the drill core scale. The folding is usually very tight, with overturned and recumbent folds common. Such structures were formed by plastic deformation of the bed contemporaneous with its deposition.

Infrequent calcareous sandstone sills and dikes resulted from penecontemporaneous deformation associated with soft sediment brecciation and sediment injection.

Imposed Diastrophic Structures

Interpretation of the configuration of the oil shales of the Albert Formation, as now arranged in space, depends to a large degree on recognition of features resulting from structural deformation of the rock units. Such features include: brecciation, slickensides, crenulation and folding, faulting and fracture filling. These characteristics predominate in the laminated marlstone lithology, are somewhat diminished in the clay marlstone and shale beds, and are of only minor significance in the massive resistant dolomite marlstones and dolostones.

In many places, brecciation is obvious. Brecciated core of the non-organic shales and the lower grade clay marlstones has often been completely rubblized by handling and weathering, but in the laminated marlstones, brecciated core has maintained competency. Such zones consist of contorted and fractured "plates" and "blocks" of slickensided fragments. Slickensides are the most pervasive evidence that post lithification movement has occurred in the oil shales of the Albert Formation (Plates 2.a, c, d, e and f), as virtually all planar surfaces in the brecciated zones are slickensided. In addition, numerous other zones of slickensided planar surfaces, invariably

parallel to bedding planes, were noted. These latter examples are often associated with kerogen rich laminae, the kerogen having functioned as a promotional agent to slippage and movement along the bedding planes.

Plots of structural attitude, which accompany the lithologic logs (Figs. 4 and 5), graphically illustrate the effect of tectonics, especially faulting, on the oil shales of the Albert Formation, particularly on the bedding angle relative to the core axis. The faults, evident in the cores by changes of dip, are often bracketed by progressively "steepening" bedding angles below, which abruptly "flatten" above the fault. The steepest bedding, directly below the fault, often exhibits drag folds and crenulated laminae.

Filling of diastrophically induced fractures is generally by calcite and albertite. By far the most significant fracture fill of the area was the albertite vein, variable from centimetres to over 5 metres thick, extending laterally for 850 metres and to a depth in excess of 425 metres, and mined to a depth of 335 metres. A vein of this thickness is unique to the area.

The filling of fractures by calcite is most evident in the laminated marlstones of the Albert Mines zone. Solution of calcite has occurred along pressure planes with subsequent re-deposition in open fractures along areas of tension separation in the tectonically induced folds (Plate 2.e).

Whether or not the faulting, through repetition, represents a significant increase of section beyond the depositional thickness is difficult to interpret. The rubble zones certainly indicate some degree of structural over-riding, but the apparent "slippage" movement along kerogen planes may be indicative of considerable deformation without significant repetition of section.

CONCEPTS OF ECONOMIC EVALUATION

Three methods can be employed to determine the potential for shale oil recoveries: visual inspection, geophysical logging and geochemical analyses. An initial guideline must be established, in this case by Fischer assay, one of the geochemical processes. These assays then form the basis for evaluations based on visual and geophysical concepts as well as other geochemical techniques.

From Fischer assay data, the laminated marlstones of the Albert Mines zone provide the greatest oil yields, averaging close to 100 litres/tonne, with maximum recoveries in excess of 160 litres/tonne and with most of the zone yielding in excess of 80 litres/tonne.

Both the clay and dolomite marlstone zones have lower shale oil yields, ranging generally from 20 to 80 litres/tonne and averaging in the range of 35 to 55 litres/tonne. Both these intervals exhibit zones of better and poorer than average recoveries. These variations are readily evident on the plots of oil yields for the Albert Mines area, and to a lesser degree on those of the more easterly and westerly core holes.

Visual Inspection

Burning in an open flame has always been a standard test for oil shales. In fair yielding zones of 40 litres/tonne or better, where a thin edge can be obtained, can generally be ignited by a consistent strong flame. Sustained combustion, without benefit of continuing applied flame, occurs at and over approximately 100 litres/tonne. For the Albert oil shales, this test can be modified and analyzed in conjunction with other visual characteristics to provide a closer estimate of potential

shale oil yield.

Holding rock samples in a standard sized flame (i.e. standard for each person's individual approach, be it a match, a lighter, an alcohol burner, or a blow-torch) will create reactions grading from nil, through brownish discolouration, discolouration and emission of smoke and/or petroliferous odor, to the actual ignition with strong odor and discolouration. Where discolouration is the only result, care must be used to differentiate kerogen destruction from deposits left on the sample by the burning flame. Obviously, in the above, the greater the flame reaction, the higher the potential yield. Care must also be taken to ensure that albertite veinlets, which burn readily, are not included in the test sample.

Colour is a significant factor as increasing brown content and depth of colour indicate increasing kerogen content. Greyer shales are leaner and light brown dolostones have low oil yields.

Lamination and fissility can be utilized together. The high yield marlstones are generally finely laminated and colour varied, but remain blocky as the kerogen binds the laminae; however, this type can be split along the kerogen planes, providing thin sheets and edges. This characteristic greatly influences the flame test results as these thin edges are readily ignited. As clay content increases in the clay marlstones, and kerogen decreases, lamination is present but the rock is more fissile as the kerogen does not bind the laminae. Although thin edges are easily obtained, ignition is more difficult because of lesser kerogen.

The dolomite marlstones have been described as laminated, non-fissile, grading to massive, with kerogen laminae ranging from abundant and laterally continuous to sparse and discontinuous, in part recognizable only as discontinuous

parallel organic flecks. The decrease in number and declining quality of the organic laminae development coincides directly with decreasing oil yields.

Kerogen is the lightest of the mineral components: high kerogen rocks have specific gravities as low as 1.9 for the laminated marlstones, 2.2 for the clay marlstones, and 2.1 for the dolomite oil shales. Without kerogen, the specific gravities of these rocks would range from 2.6 to 2.9: this difference, which increases with increasing kerogen, is easily apparent from the "heft" of rock specimens.

No guide can be prepared by which a casual observer can use the above features to estimate oil yield without prior practice. By study of available cores, in conjunction with known Fischer assay results, the observer should be able, with experience, to estimate potential oil yield within ±25% of the assay value from visual inspection. Although this would be unsatisfactory for economic evaluation, a general fairly accurate (yield average) evaluation of any core hole should be immediately available without having to await the time-consuming geochemical studies.

Geophysical Logs

Downhole logs were run at all core holes of the Can. Oxy. program: these include density and gamma-neutron curves at all 6 locations, caliper curves at 5, and electrical log spontaneous potential-resistivity curves at 3 of the holes. No direct correlation of oil shale quality to the gamma-neutron and spontaneous potential-resistivity logs is immediately evident; however, data may be insufficient to provide a proper evaluation of these logs for oil shale interpretations. The availability of many drill core density determinations has allowed density to be assessed as an exploration tool from the few available logs.

In addition to the Fischer assays, bulk densities of the rock samples were determined at all Can. Oxy. core holes: rock density values were obtained for all samples of this project. These determinations provide the essential background for interpretation of density log potential.

Density vs. Yield: Density versus yeild plots were made on the basis of lithologic zonation for all data of each unit in the Albert Mines area (Fig. 7a to d). Although the specific points were in all cases contained within widely variable ranges, a visually defined average line was evident for each zone.

Each zone exhibits its own slope to the yield-density plot (Fig. 8), with the change in slope apparently responding to the changes in dolomite-clay ratio and kerogen content. Dolomite (density 2.8-2.9 g/cc) is much heavier than the clay component (2.0-2.6 g/cc) where density decreases from kaolin-illite to the mixed layer clays as additional lattice water is present. The laminated marlstone slope is close to that of the clay marlstone, whereby the greater carbonate content of the laminated zone is offset by the increased kerogen content.

Dolomite marlstones will yield shale oil from rocks of higher densities than will the laminated and clay marlstones: in contrast dolomite marlstones yield less shale oil at equivalent lower densities than the laminated marlstones.

The density versus yield average curves of the laminated, clay and dolomite marlstone zones essentially intersect at a common point of density 2.33 g/cc, yield 55 litres/tonne. The upper zone does not follow this pattern. The rocks of the upper zone are much more variable than are those of the other units, as oil shales of the upper zone are composed of all 3 lithotypes.

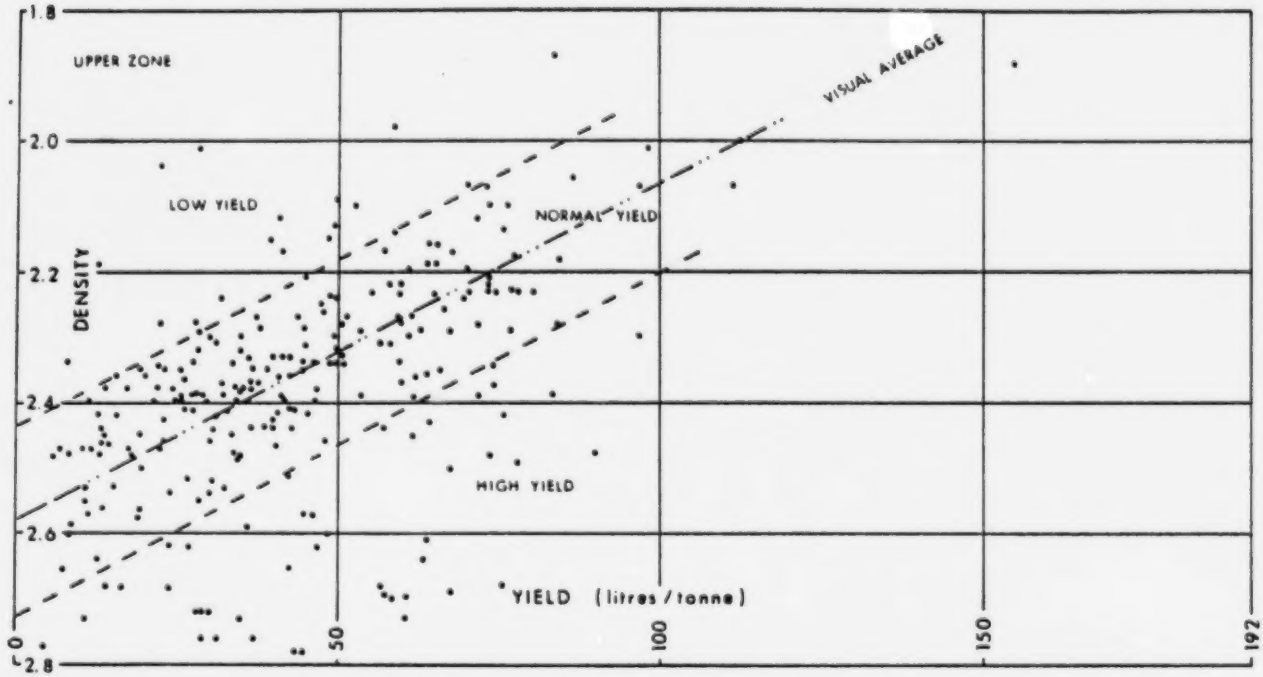


Figure 7a: Rock density vs. Fischer Assay yields, Albert Mines area: Upper Zone

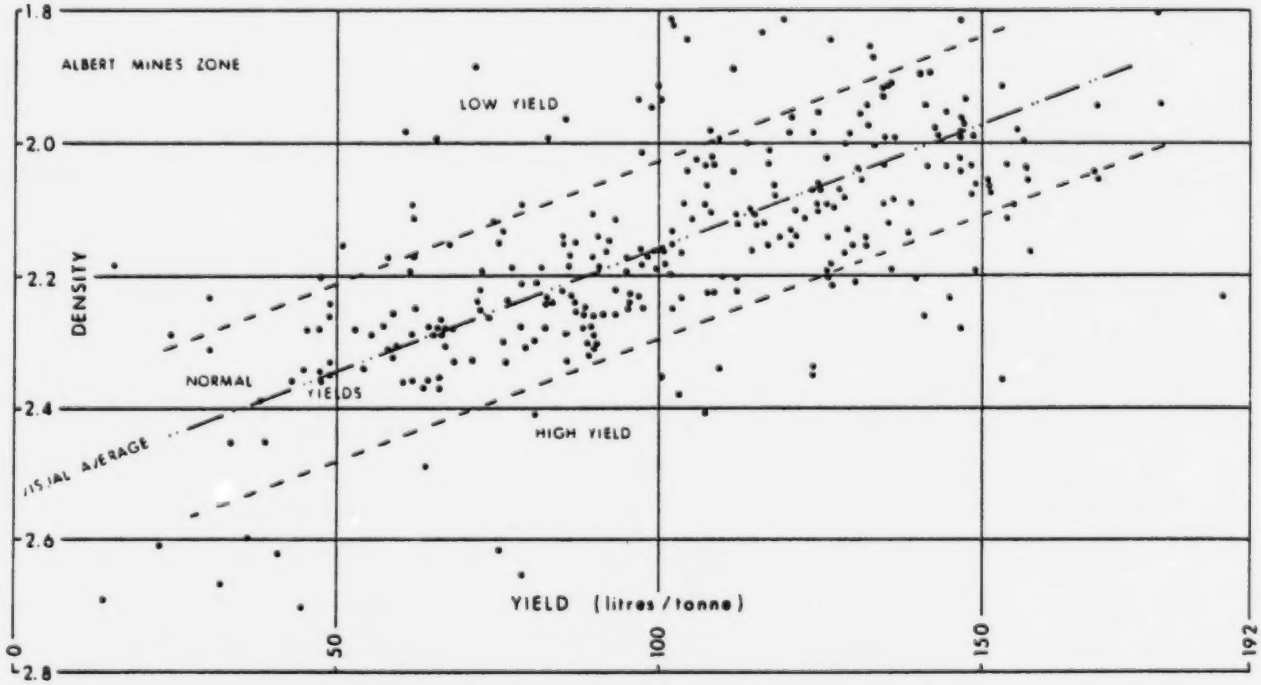


Figure 7b: Rock density vs. Fischer Assay yields, Albert Mines area: Albert Mines Zone

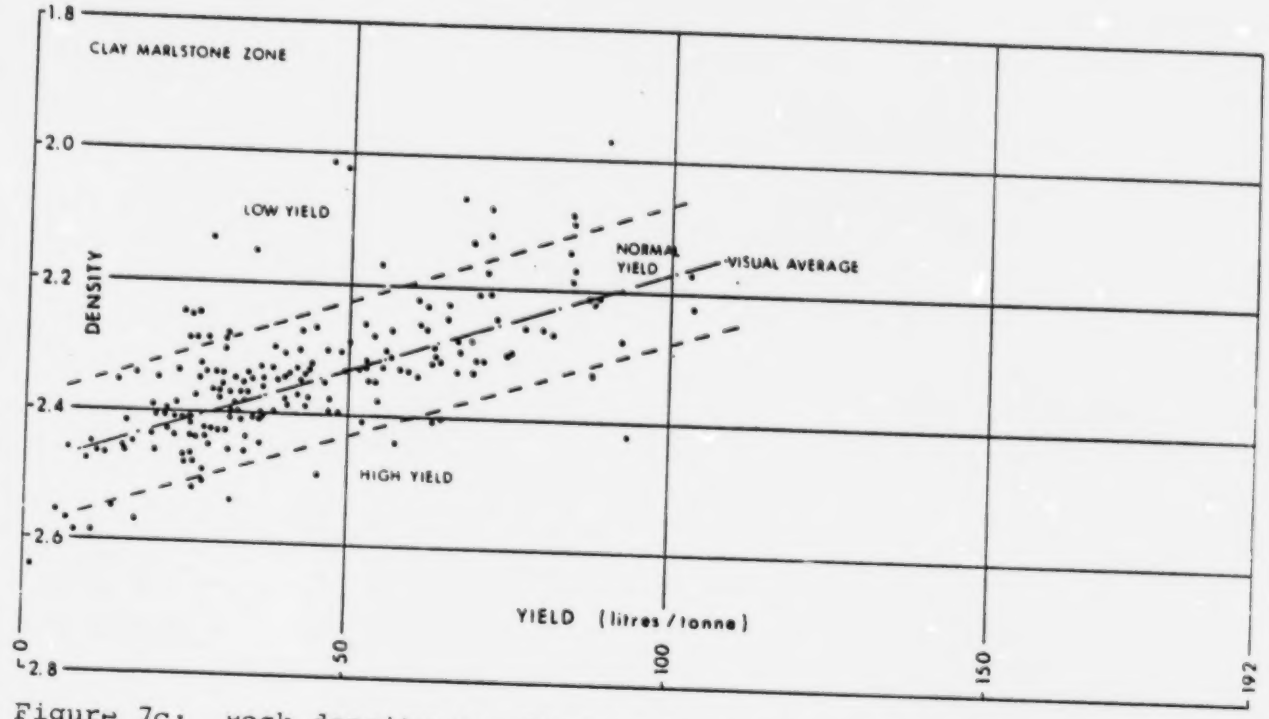


Figure 7c: Rock density vs. Fischer Assay yields, Albert Mines: Clay Marlstone Zone

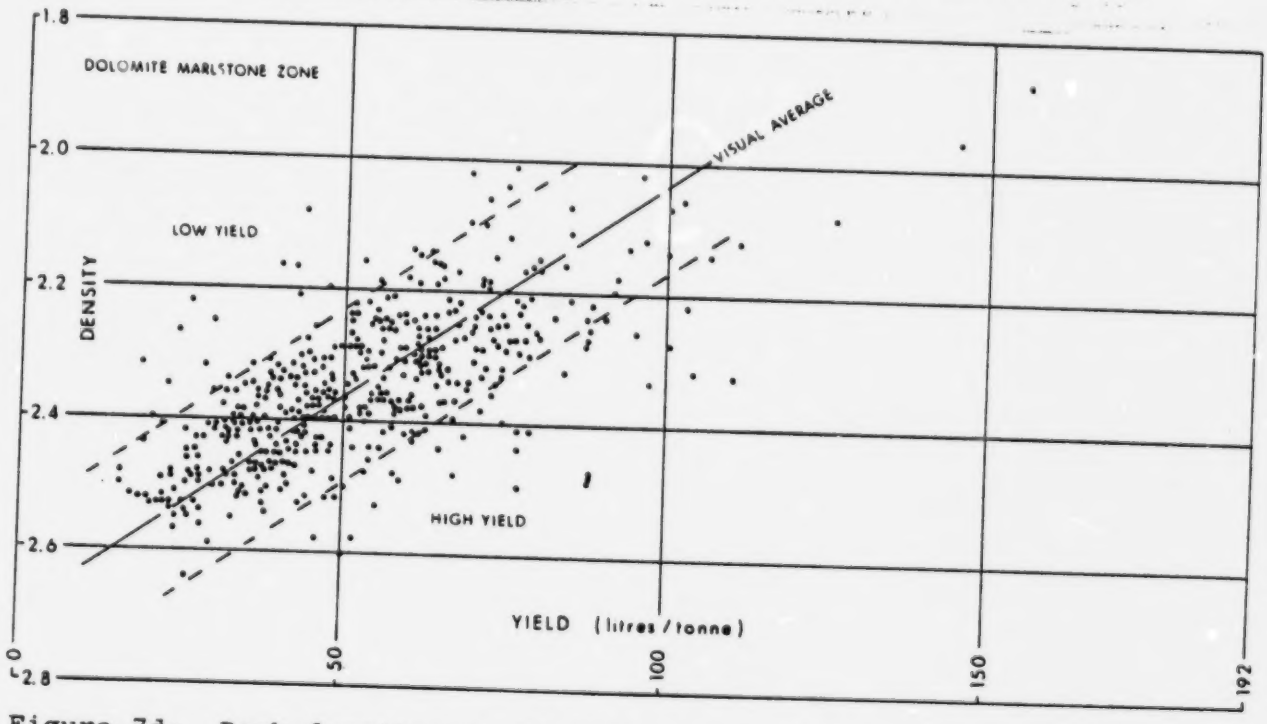


Figure 7d: Rock density vs. Fischer Assay yields, Albert Mines: Dolomite Marlstone Zone

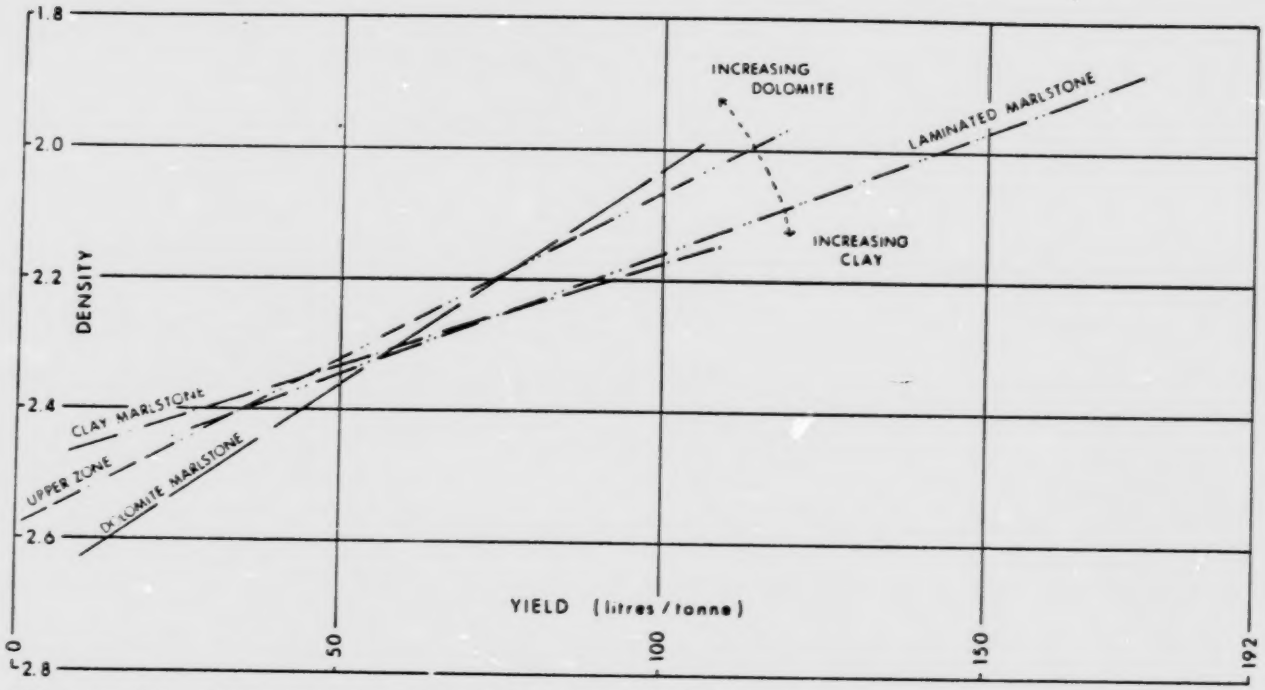


Figure 8: Comparative density vs. yield averages for lithologic sub-units, Albert Mines area

Although the majority of points fall into distinct bands (Figs. 7a to d), certain points fall outside the norm. These may result where albertite grains or veinlets provide yields much in excess of that anticipated for the rock density, or, in contrast, low yields from low density samples may be attributed to greater maturation of kerogen in slickensided, brecciated, faulted zones. These abnormalities become increasingly evident upward in the section as the diascrophically disturbed features become more common. These variations may, however, be related entirely to difficulties in uniform sampling.

An attempt was made to define the average curves by computer with the regressive equation $y = ax + a_1x^1 + a_2x^2$; however, this was unsuccessful as neither yield nor density is sufficiently regular to be a satisfactory independent variable. A more complex computer program should define a more accurate curve than is provided by the visual plots presented herein.

Density Log: From a comparison of the downhole density log to the measured rock densities (Figs. 4 and 5), the density logs are relatively coincident but are offset slightly toward denser values. Any adjustment to compensate for this minor difference should be easily calculated.

Use of the density log to calculate average yields by measurement of area under the curve should provide adequate average results so that, within a development drilling program, not all holes would need to be cored.

In addition to the adjustment of base density values from rock to log, interpretations will have to be made by zone, with yield values determined by parameters of the density versus yield curves for each lithotype. More holes must be cored and logged, and an adequate computer program utilized, to establish proper yield versus density curves for each zone. Density logs will then be an excellent exploration-development tool for oil shales. Whether or not a single curve can be defined and applied to all zones should be part of future computer investigations.

Similar zonal analyses will also be essential for other areas as the excellent laminated marlstones of the Albert Mines area are not yet recognized elsewhere, and maturation of the kerogen may vary from area to area. From the limited data of Can. Oxy. Rosevale 1 (Fig. 5), slopes appeared similar (plots not reproduced herein), but average lines were offset from those of the Albert Mines area.

Organic Geochemistry

Fischer assays have been the basic tool for the geochemical analysis throughout the history of North American oil shale exploration: the development of the Rock-eval pyrolysis

technique, and the utilization of total organic content values, have added a significant new dimension to oil shale investigation. Because of the authors' limited background concerning these newer concepts, a specific note of appreciation must be made to T. G. Powell and L. R. Snowden, Institute of Sedimentary and Petroleum Geology, Calgary, whose guidance and interpretive assistance were essential to this section of the study.

Approximately 500 grams of rock were required to provide sufficient crushed sample to undertake the various analyses. Because all cores had previously been split for Fischer assays, a core length of 10 to 25 centimetres was necessary to provide the required rock weight. The rock types, as illustrated in Plates 1 and 2, readily reveal the difficulty in acquiring sufficient rock interval of the uniform character and composition desired for comparative analyses. Badly rubbled core, because of inadequate storage, added to this problem. Many instances of data incompatability, mostly minor, can be recognized; however, the statistical averages, considering that only 129 samples were used, appear to be quite accurate and meaningful.

Fischer Assays: All cores available to this study have been previously analyzed by the Fischer assay process. Most were assayed by crushing and sampling over 5 foot (1.5m) intervals, but with zones of 2 foot and 1 foot (0.6 and 0.3m) sampling in the more significant oil shale sections. These data are plotted on the core hole logs in histogram form, including three important values, shale oil yield, shale oil gravity and water yield (Figs. 4 and 5). Copies of these data are on file at the New Brunswick Department of Natural Resources.

Considering the difference of sampling technique from the original analyses to those of this report, the results are sufficiently close that no apparent loss of oil potential or kerogen disintegration has occurred over the years since the

cores were cut; consequently, a comparison of present geochemical data to the previous results is considered valid.

Shale Oil Yield: The high yield laminated marlstones of the Albert Mines zone are readily discernible on an oil yield plot (Fig. 4, Can. Oxy Albert Mines 2, 4, 5 and Atlantic-Richfield Albert Mines 1A), wherein the yield averages approach 100 litres/tonne. The other zones are not distinctly defined by yield alone.

All zones appear to contain intervals of better and poorer average yield. A slightly lower yield can be interpreted in the lower upper half of the Albert Mines zone: a higher yield interval may be present medially in the clay marlstone: the dolomite marlstone zone appears to be a series of alternating higher and lower yield sub-zones (Fig. 4, Can. Oxy. Albert Mines 5, 6). Because of the structural complexities and the resultant difficulty to define true depositional thicknesses, no attempt has been made to correlate better yield intervals within the limited core hole data available; however, such a sub-zonation should be constantly appraised as exploration and development continue in the Albert Mines area.

Because the high yield laminated marlstones of the Albert Mines zone are not presently recognized beyond the local Albert Mines area, zones are not recognizable to the east (Boudreau-Dover) or to the west (Rosevale-Urney) on yield plots alone (Fig. 5). A similar alteration of higher and lower yield gross intervals are evident in AtlanticRichfield Boudreau 1 (Fig. 4). This effect may be economically significant as many of the higher yield intervals in the Albert Mines and dolomite marlstone zonal equivalents are 20 to 30 metres in thickness and generally yield in excess of 50 litres/tonne, a potentially acceptable mining unit. A closer inspection of sub-zones within the presently known lithologic subdivisions will be essential to appropriate economic evaluation.

Shale Oil Gravity: Specific gravity data for the recovered shale oil vary somewhat from the original assays to those of the present study. The more recent determinations are much more uniform throughout each borehole than are the widely fluctuating values plotted as histograms from the original data. This could represent a loss of bituminous phase by weathering since the cores were cut, but several zones show lower average specific gravity now, the inverse to that expected from organic deterioration. Some now also indicate generally higher specific gravity values. These differences may be attributed to crushing technique and possibly to present more efficient temperature control during the Fischer assay process.

From the original core data, the average specific gravity of the Frederick Brook oil shale interval in the Albert Mines area is 0.872 (30.77°, API), with very minimal changes from zone to zone (upper, 0.869/31.33°; Albert Mines, 0.876/30.02°; clay marlstone, 0.864/32.27°; dolomite marlstone, 0.874/30.40°). The zones with greater clay content yield slightly better quality shale oil but the variations are not particularly significant.

In the Urney-Rosevale and Boudreau-Dover areas (Fig. 5), yields are generally lower than at Albert Mines, and the oil specific gravities were often reported as "averaged" over thick intervals: probably the yields were generally too low to provide adequate sample for gravity determinations. At Can. Oxy. Rosevale, the more recent samples indicate an average S.G. at 0.890 (27.49°, API), somewhat lower than 0.907 (24.51°, API) from the core assays. In contrast, the initial results at AtlanticRichfield Dover 1A average 0.871 (30.96°, API) in contrast to the few samples of this study at a much higher 0.907 (24.51°, API) average specific gravity.

Because the present determinations range above and below those of the assays made when the core was fresh, the

variations are considered attributable to sampling methods and to present day improvement in analytical technique rather than to loss of hydrocarbon from the core by weathering.

Water Yield: The high water yield of the clay marlstone zone in the Albert Mines area (Fig. 4) provided the first significant clue to the zonal definition of the oil shale interval. Because of the near-surface position of this zone at some locations, in conjunction with the abundant brecciation and faulting, downward movement of surface waters was suspected, but the relationship of higher water yields to the shalier (greater clay) lithotypes was readily apparent when all logs had been prepared.

If surface waters had been involved, the analytical data should have changed since the cores were cut; however, the excellent correlation of the new water yield data to older analyses, in conjunction with the clay mineralogy data, confirms the water yield as a by-product of clay disintegration during pyrolysis.

Correlations westerly and easterly of the Albert Mines area were based initially on recognition of the higher water yield zone, especially at AtlanticRichfield Boudreau 1, Can. Oxy. Rosevale 1, and AtlanticRichfield Urney 1. The underlying dolomite marlstones contain very little water, whereas the laminated marlstones are medial, having less water than the zones with greater clay, but generally more than the dolomite marlstones.

Organic Carbon

Analyses for total organic carbon content were conducted commercially in conjunction with the Rock-eval pyrolyses. Total carbon content was also determined at the Institute of

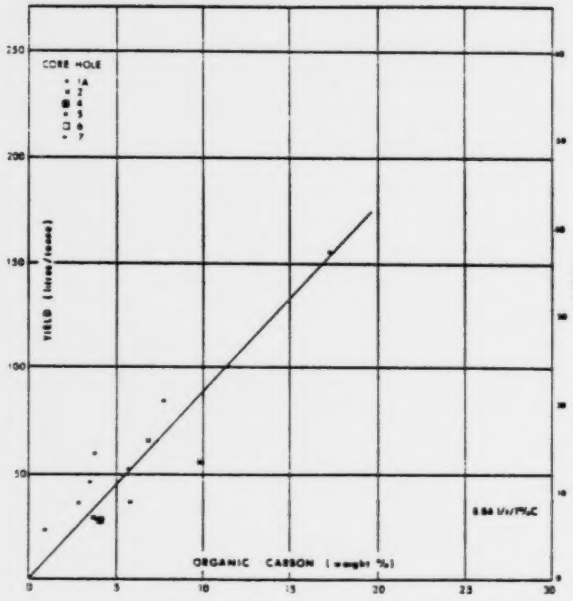
Sedimentary and Petroleum Geology in Calgary. Some variations were anticipated due to sampling, but the Institute of Sedimentary and Petroleum Geology data averaged 120% of the commercially reported values (Appendix 4). The generally higher Institute of Sedimentary and Petroleum Geology values have here been used.

When plotted against organic carbon values, yields from 129 samples averaged 8.67 litres/tonne (2.08 U.S. gallons/ton) per 1% organic carbon, basically without deviation from a straight line relationship in any quantity range.

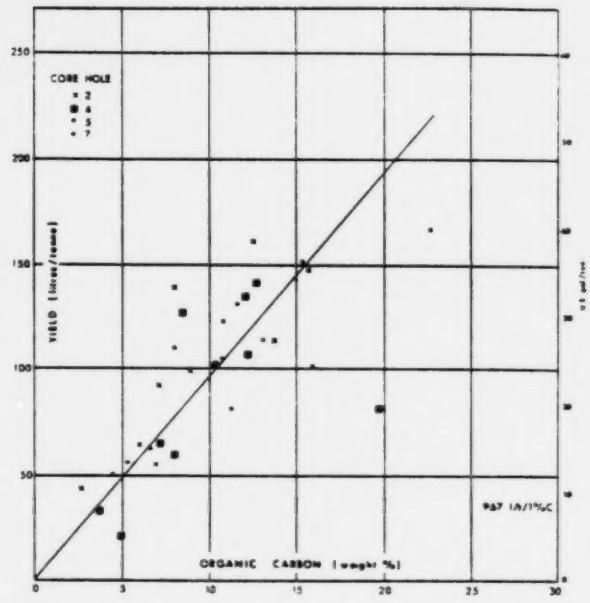
On closer examination, some variation is evident for the lithologic zones of the Albert Mines area. Visually averaged plots indicate a maximum yield/1% organic carbon of 9.67 litres/tonne in the laminated marlstones of the Albert Mines zone, decreasing to 9.00 and 8.84 litres/tonne in the clay marlstone and upper zones, and further to 8.51 litres/tonne in the dolomite marlstone (Figs. 9a to d). Undoubtedly these results reflect the ease with which kerogen can be retorted relative to the degree of laminar development, such as the disseminated flecks common to dolomite marlstones (Plate 2.a) in contrast to the excellent laminar types (Plate 2.d). The actual yield variation across the zones is not great, as the lowest is 88% of the highest.

Insufficient data are available to assess properly lithologic zones in the other areas. Average yields from all samples are 8.40 litres/tonne at AtlanticRichfield Boudreau 1 and 8.00 litres/tonne at Can. Oxy. Rosevale 1, both per 1% organic carbon (Figs. 10a, b). In these areas, from the few data, both total yields and yields relative to organic carbon are less than in the Albert Mines area.

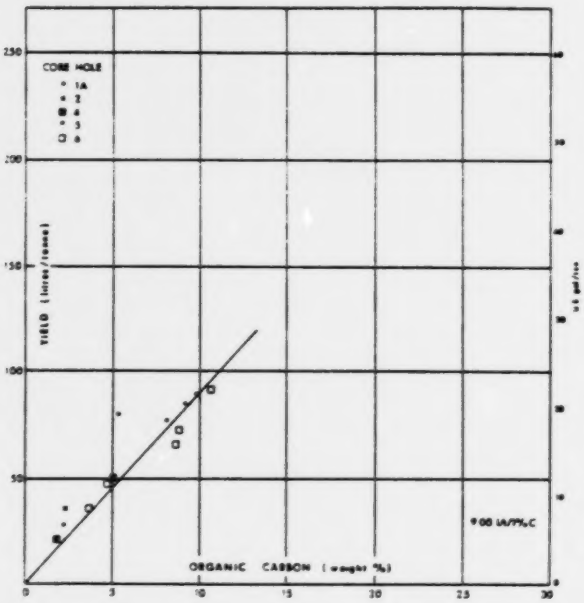
From all Albert Mines data, the average organic carbon content is 7.09%, ranging to a maximum 29.40% which



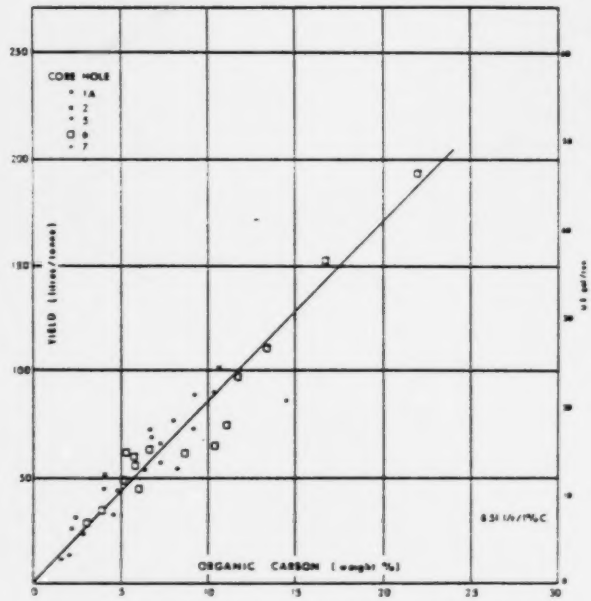
a: Upper Zone



b: Albert Mines Zone



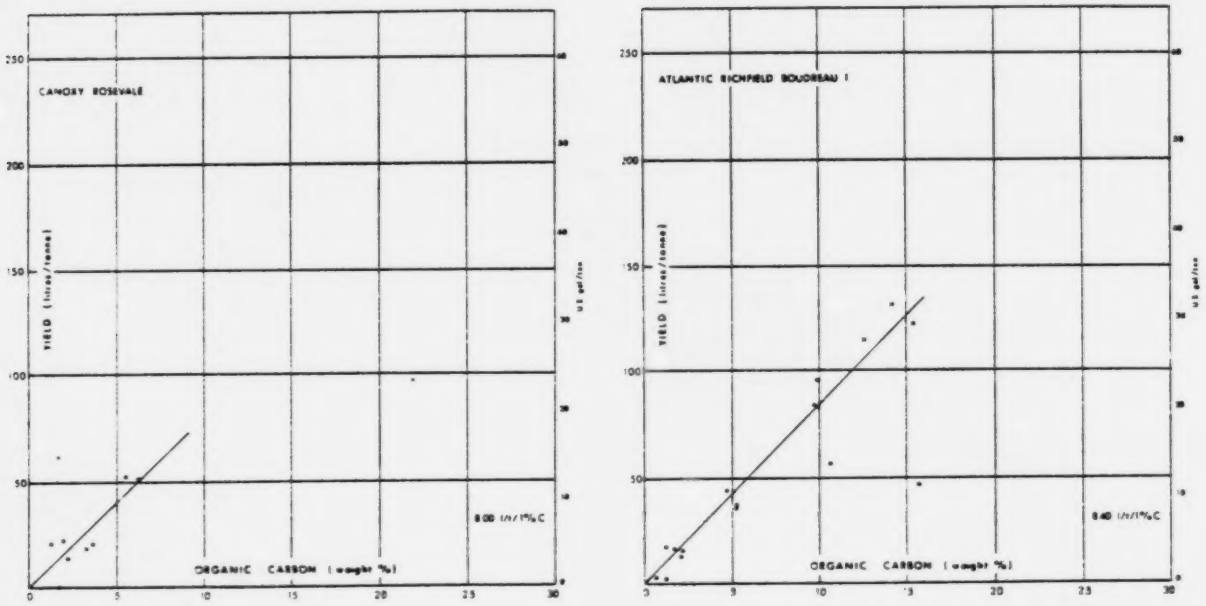
c: Clay Marlstone Zone



d: Dolomite Marlstone Zone

Figure 9: Fischer Assay yield vs. organic carbon content, Albert Mines area

assayed 263 litres/tonne. At Boudreau, average organic carbon is 6.44%, and is even lower, 3.20%, from the limited Rosevale data.



a: Can. Oxy. Rosevale 1 b: AtlanticRichfield Boudreau 1

Figure 10: Fischer Assay yield vs. organic carbon content

Rock-eval Pyrolyses

Several new factors, not previously investigated for the Albert oil shales, can be interpreted from the Rock-eval pyrolyses. Both the kerogen type and the maturation stage of the kerogen are significant to the quality and quantity of the recovered shale oil. The interpreted "petroleum potential" is directly comparable to Fischer assays, but also differentiates petroleum versus kerogen components of the oil shale product. Appendix 4 lists all data involved in the Rock-eval process.

Kerogen: Espitalie *et al.* (1977) report that the "hydrogen index" (mg. HC/g. org.C) and "oxygen index"

(mg.CO_2/g. org.C) correlate closely to the atomic H/C and O/C ratios obtained by analyses of kerogens. The indices can then be used to construct a basic diagram of kerogen types (I, II, III) similar to and equatable to that defined by the H/C and O/C ratios. The index curves of kerogen type are produced as a background on Figure 11 for classification of the Albert oil shales. Type I is considered to be of algal origin, normally lacustrine: type II is derived from marine deposits, whereas type III has organic matter of terrestrial humic origin. The extremely low oxygen content of type I has been attributed to bacterial reworking during deposition of the organic component with development of a waxy kerogen residue.

The hydrogen/oxygen indices plot for all Albert Mines area samples (Fig. 11a) indicates the kerogen to be type I with a minimum oxygen content, much less than would normally be anticipated, and only a few samples showing any degree of maturation by reduced hydrogen index values. The kerogen is very immature; probably little, if any, hydrocarbon has been generated from this area. There is no indication of any significant humic content: none was noted in the cores of this area.

At the Rosevale-Urney area, westerly of Albert Mines, type I kerogen is again indicated, also low in oxygen but not quite so pronounced as at Albert Mines, and with some degree of maturation exhibited by the spread of hydrogen index values (Fig. 11b). This correlates to the lesser shale oil yields per 1% organic carbon indicated for this area.

Easterly of Albert Mines, at Boudreau and Dover (Fig. 11c) kerogen is again basically type I, but with a few samples of possible type II and/or III. These are from the upper zone, the only oil shale interval in which carbonaceous plant debris was noted in the cores. Humic material was also recorded in coarser phase sandstones of the Hiram Brook facies.

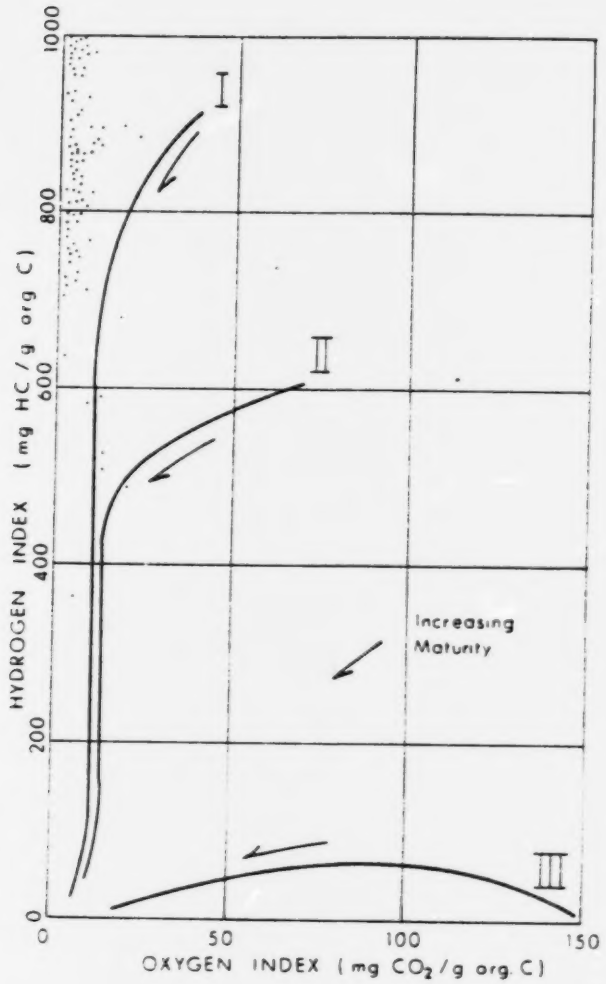


Figure 11a: Hydrogen index vs. oxygen index, Rock-eval analyses, Albert Mines area

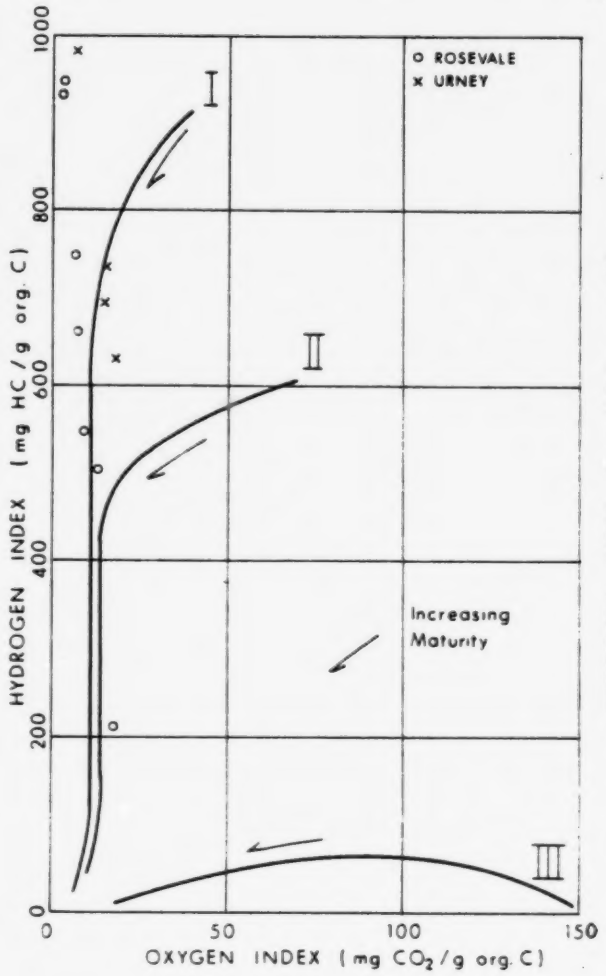


Figure 11b: Hydrogen index vs. oxygen index, Rock-eval analyses, Urney-Rosevale area

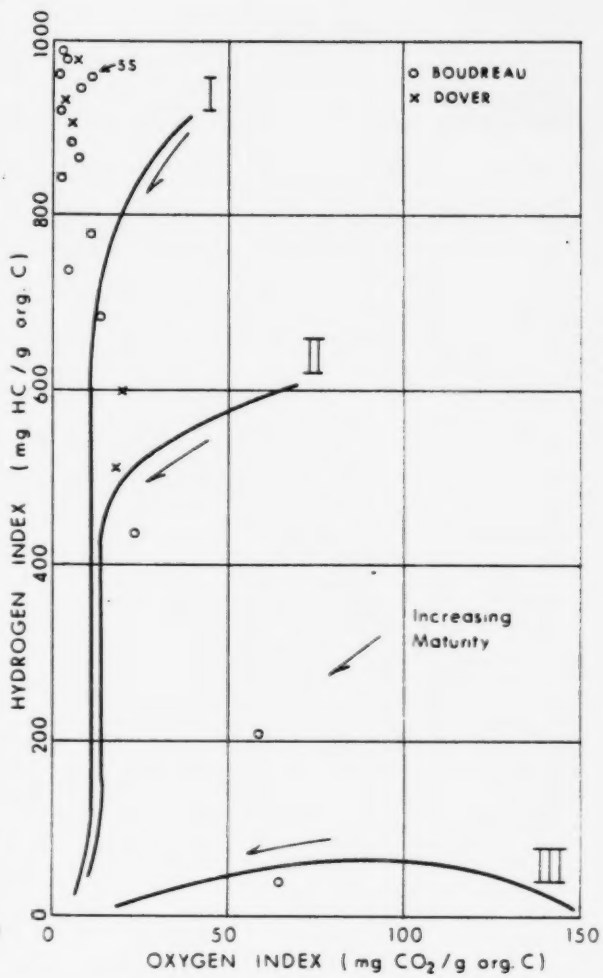


Figure 11c: Hydrogen index vs. oxygen index, Rock-eval analyses, Boudreau-Dover area

Maturation at Boudreau-Dover may be slightly greater than at Albert Mines but is less than at Rosevale, again directly correlative to the intermediate yield per 1% organic carbon indicated for this area.

Comparisons of the hydrogen/oxygen indices indicate that the same organisms provided the base for the kerogen and that essentially the same processes of kerogen development have occurred in each area and for each lithotype. An additional humic source of kerogen may be present locally in the upper zone or in local oil shale beds within the Hiram Brook facies.

Hydrogen indices above 200 mg.HC/g. org. carbon indicate excellent oil source rock: this, coupled with the low oxygen indices, explains the better than average specific gravity (0.870/31.14°) of the Albert Formation shale oil relative to the normally anticipated range (0.910/23.99°-0.980/12.89°) of gravities.

Hydrocarbon Potential: Two hydrocarbon peaks are present in the Rock-eval pyrologram curve, S_1, which measures the low temperature bitumen and free hydrocarbon phase, and S_2, representing the retorted shale oil from the kerogen and possibly some bitumen. The addition of these two products (S_1+S_2) represents the shale oil potential of the sample, measured in mg./g., which is directly equivalent to kg./tonne. Data were plotted for the hydrocarbon potential values versus Fischer assay yields in litres/tonne and the straight line average ratio established S_1+S_2/(litres/tonne) = 0.88, the latter number representing the specific gravity of the oil (Fig. 12). This is the standard conversion equation between oil reported in weight relative to volume in the metric system. Because the calculated specific gravity is here virtually equal to the measured specific gravity, the Rock-eval and Fischer assay techniques have duplicated each other for average oil yield values. Figure 13 demonstrates the direct relationship between organic carbon, Rock-eval pyrolyses and Fischer assay

data for 3 locations, one each at Albert Mines, Rosevale and Boudreau.

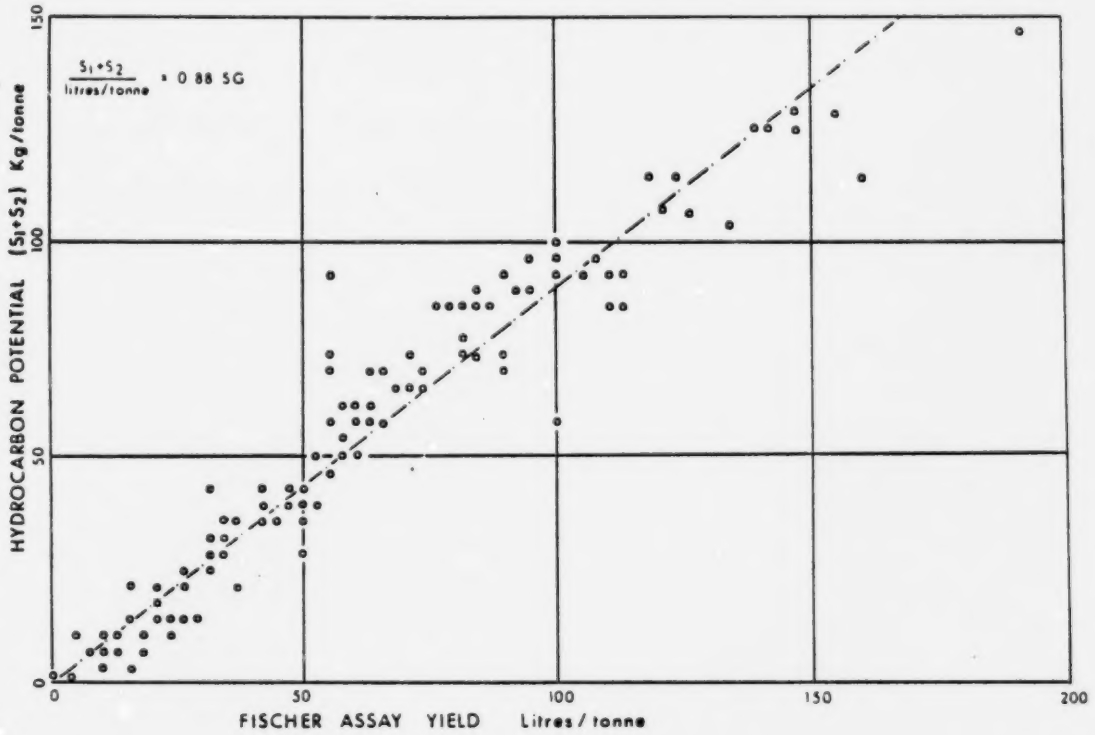


Figure 12: Hydrocarbon Potential (Rock-eval) vs. Fischer Assay yields, Albert Mines area

Production Index: Also called the transformation ratio, the production index, $S_1/(S_1+S_2)$ (Appendix 4), also defines the maturation of the organic content by comparison of the generated oil-bitumen phase to the total hydrocarbon potential of the rock. Where the production index is less than 0.4, there has been little maturation of the kerogen: over the 129 samples, 0.147 is the average transformation ratio. Only two figures exceed 0.4: one is the plant-containing type III sample at Boudreau and the other is a Round Hill conglomerate sample at Can. Oxy. Albert Mines 7.

In theory, sandstones and conglomerates cannot be oil shales because of the inability of kerogen to survive the

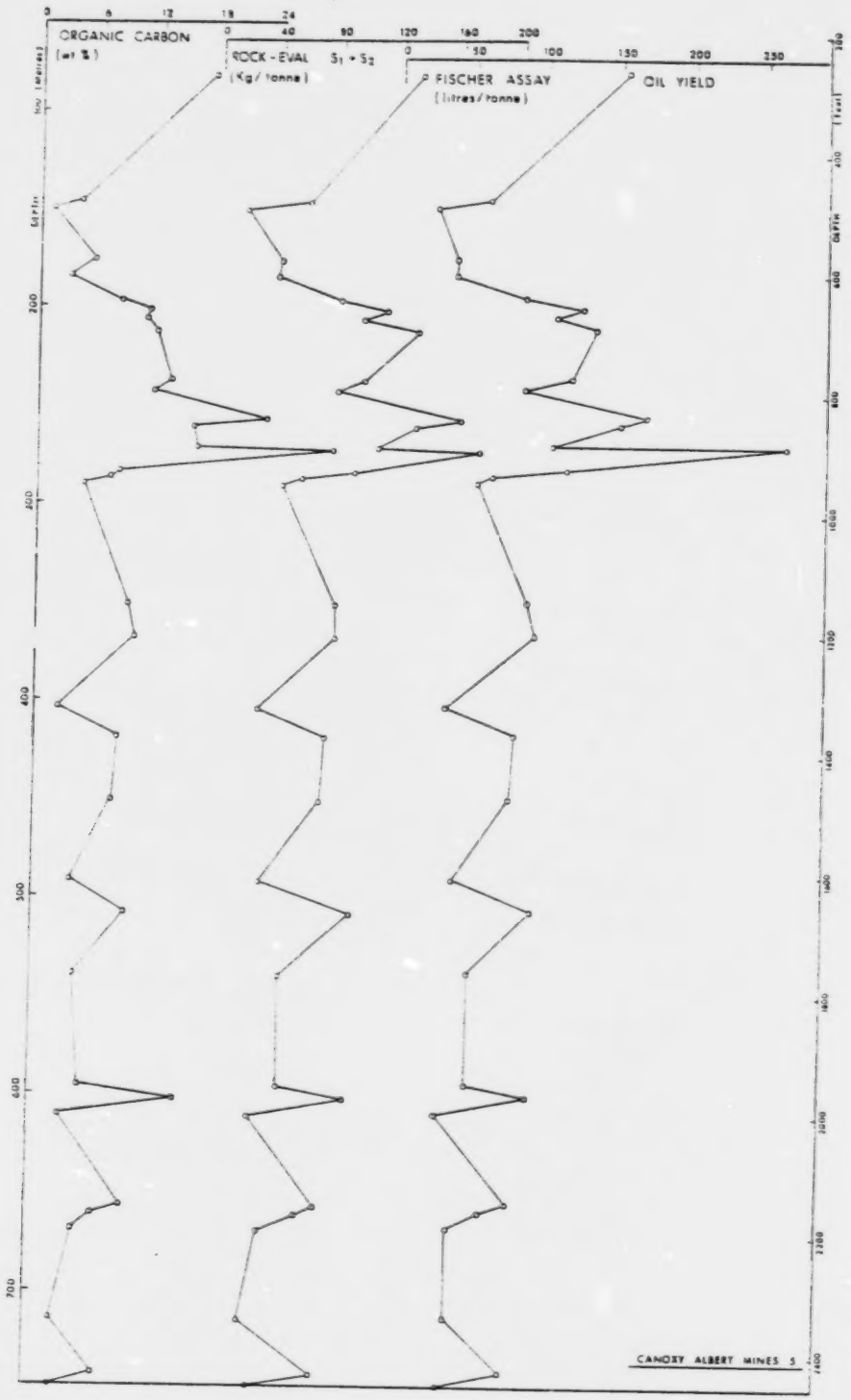


Figure 13a: Diagrammatic comparison of total carbon, Rock-eval Pyrolyses, and Fischer Assay results, Can. Oxy. Albert Mines 5

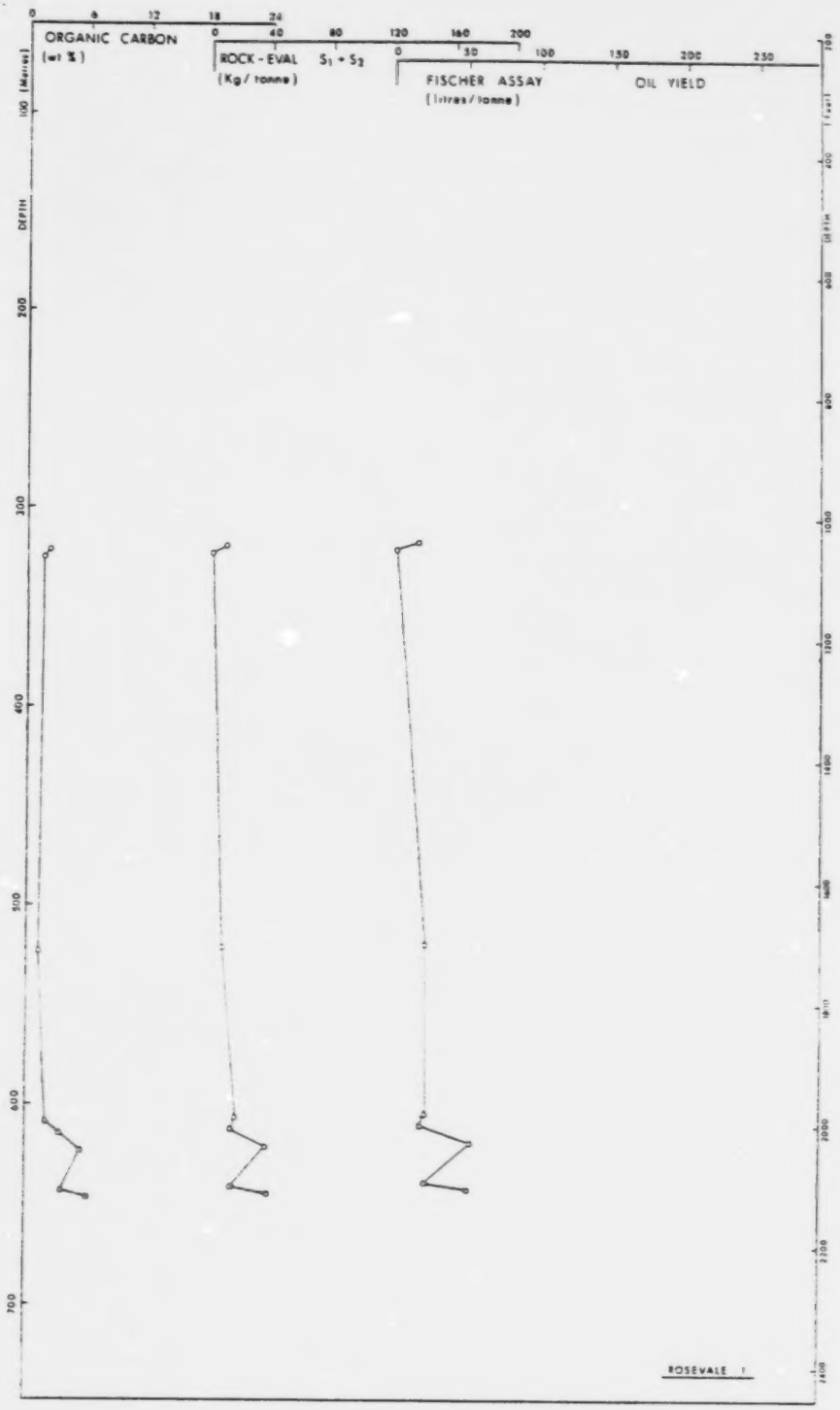


Figure 13b: Diagrammatic comparison of total carbon, Rock-eval Pyrolyses, and Fischer Assay results, Can. Oxy. Rosevale 1

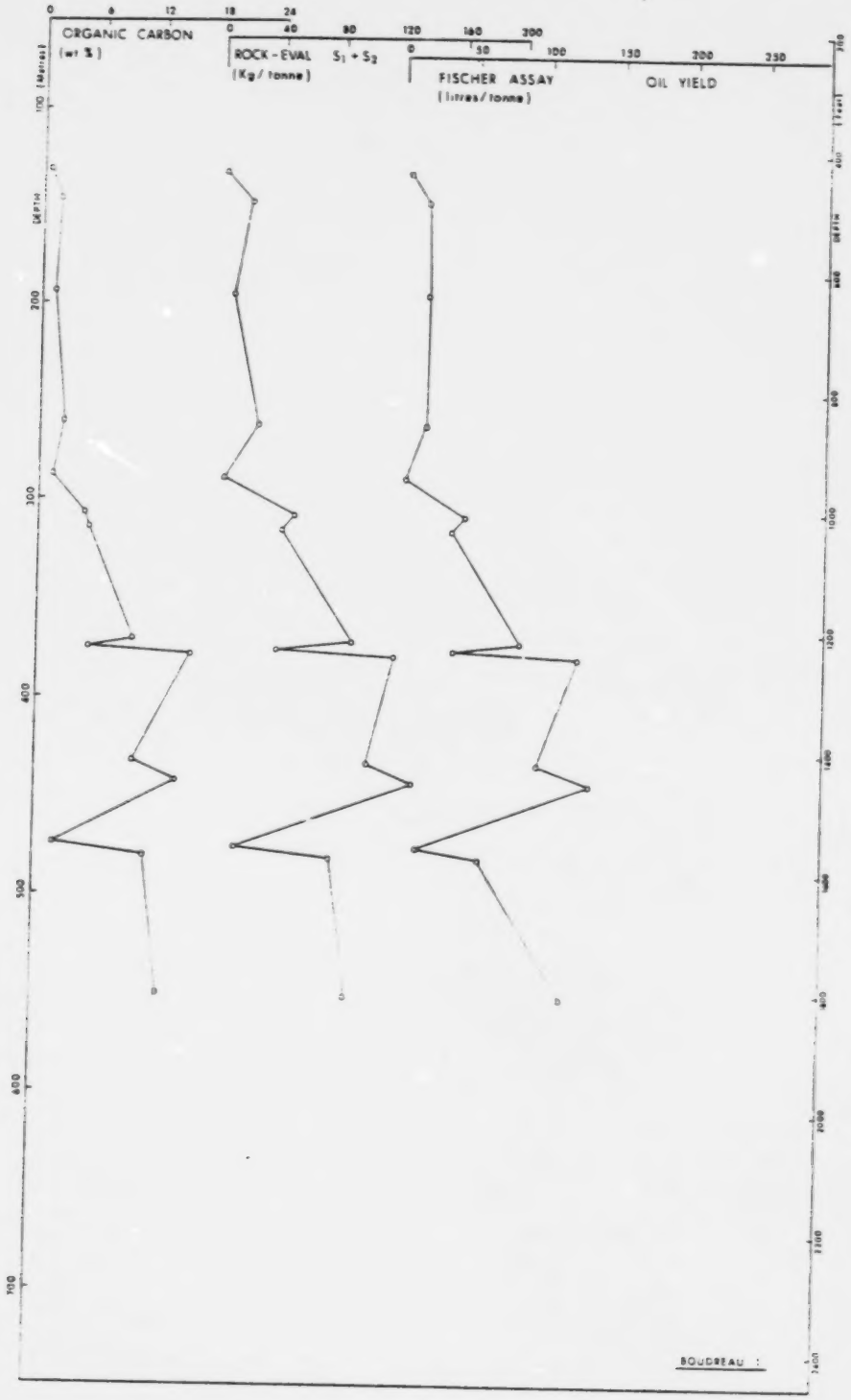


Figure 13c: Diagrammatic comparison of total carbon, Rock-eval Pyrolyses, and Fischer Assay results, Atlantic-Richfield Boudreau 1

water turbulence attributed to deposition of these coarser clastic materials. Two conglomerate samples, number 5A and 8 at Can. Oxy. Albert Mines 7, and one sandstone, number 2 at AtlanticRichfield Boudreau 1, were incorporated into the sample series to determine the reaction of apparent oil saturation (or residual oil) within the series of geochemical tests. Except for slight increases of two samples in the transformation ratio, but still indicating minimal oil content, these samples are indiscernible from the other data. Either these coarse clastics contain kerogen, migrated bitumen (albertite) or migrated oil that has been almost completely degraded to a low quality bitumen. The conglomerates appear to have a dolomite marl matrix and sandstones grade to sandy dolomite marlstones. Rip-up clasts and sand-dolomite pseudonodules do not interfere with kerogen distribution. The sandstone and conglomerates appear to be dump material deposited on the lake bottom with little disruption of water-sediment interface conditions. More study is warranted to determine the nature of the hydrocarbons in the sandstone-conglomerate facies within the oil shale sequence.

SPECIFIC SITE EVALUATIONS

Albert Mines

The oil shales and albertite vein, cropping out along Frederick Brook approximately 4 kilometres west of the village of Albert Mines in southwestern New Brunswick (Fig. 2), have been the focus of repeated interest since the mid-mineteenth century. Unfortunately, the cores from 36 holes of the Canada Department of Mines program in 1942 have all been discarded; however, the AtlanticRichfield Company (1 hole in 1968) and Canadian Occidental Petroleum Company (7 holes in 1976) cores from eight locations have been retained. Detailed lithologic and geochemical logs from six of these holes (Fig. 4), in conjunction with field notes made by McLeod (1980), are the basis for the geological interpretation of bedrock geology (Fig. 14) and the lithofacies relationships illustrated by cross section (Fig. 15).

The interdigitation of the Round Hill, Hiram Brook, Dawson Settlement and Frederick Brook Members is pronounced adjacent to the Caledonia Uplift, and is particularly evident at the west in Can. Oxy. Albert Mines 7, 4 and 6 (Fig. 4), with the distinction of Hiram Brook and Dawson Settlement Members being one of position relative to the Albert Mines zone (Fig. 3). Across this local area, the Albert Formation becomes finer eastward (Fig. 15) as conglomerate, sand and silt detritus decrease with distance from source. This is economically significant for easterly increasing potential yield and for reduced mining difficulties as the harder coarse clastic facies decreases.

McLeod (1980) placed the Albert Formation at Albert Mines in fault contact with both the pre-Carboniferous rocks of the Caledonia Uplift at the west and the Hillsborough conglomerates

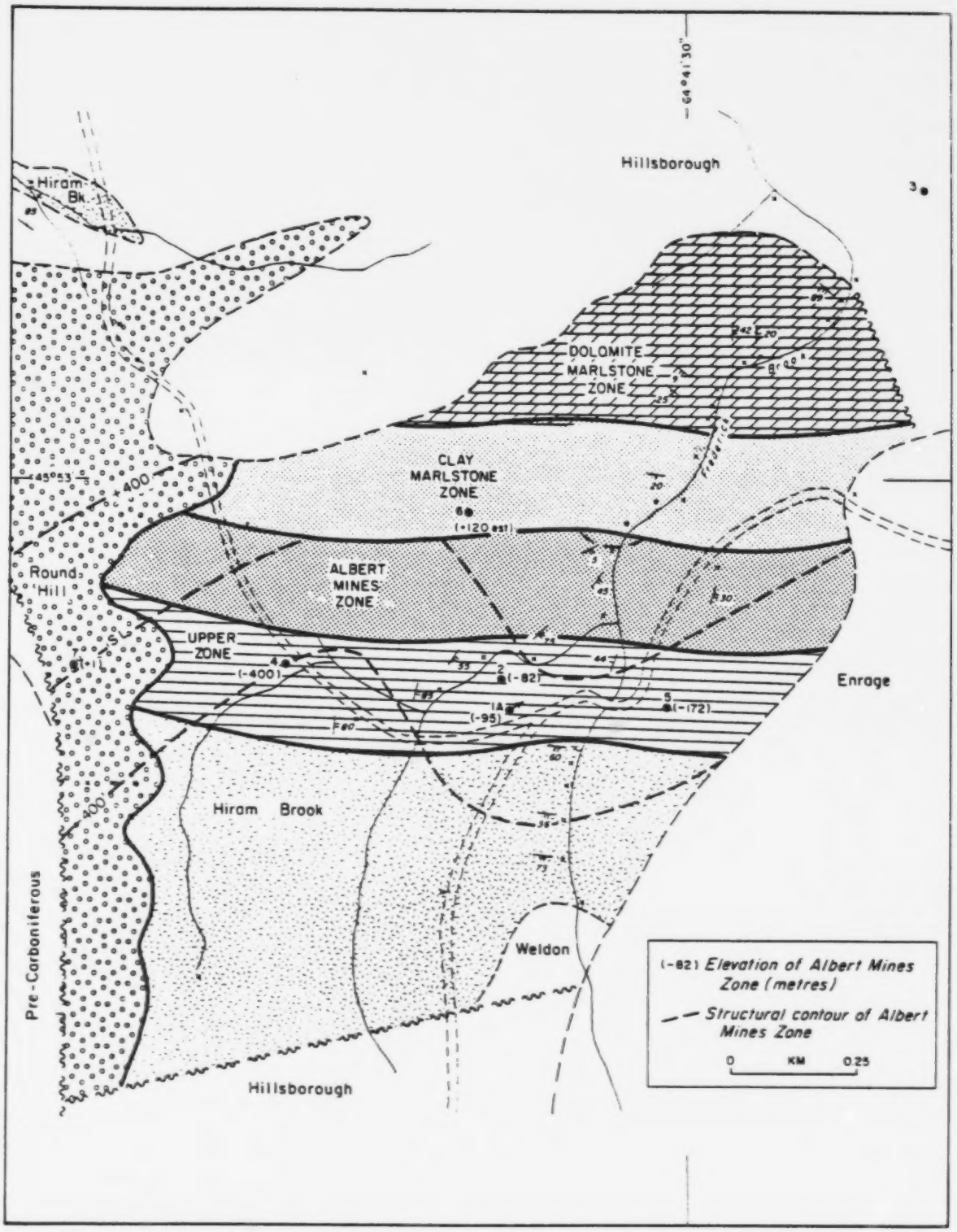


Figure 14: Interpreted surface geology, Albert Mines area, with subsurface contours in the Albert Mines Zone

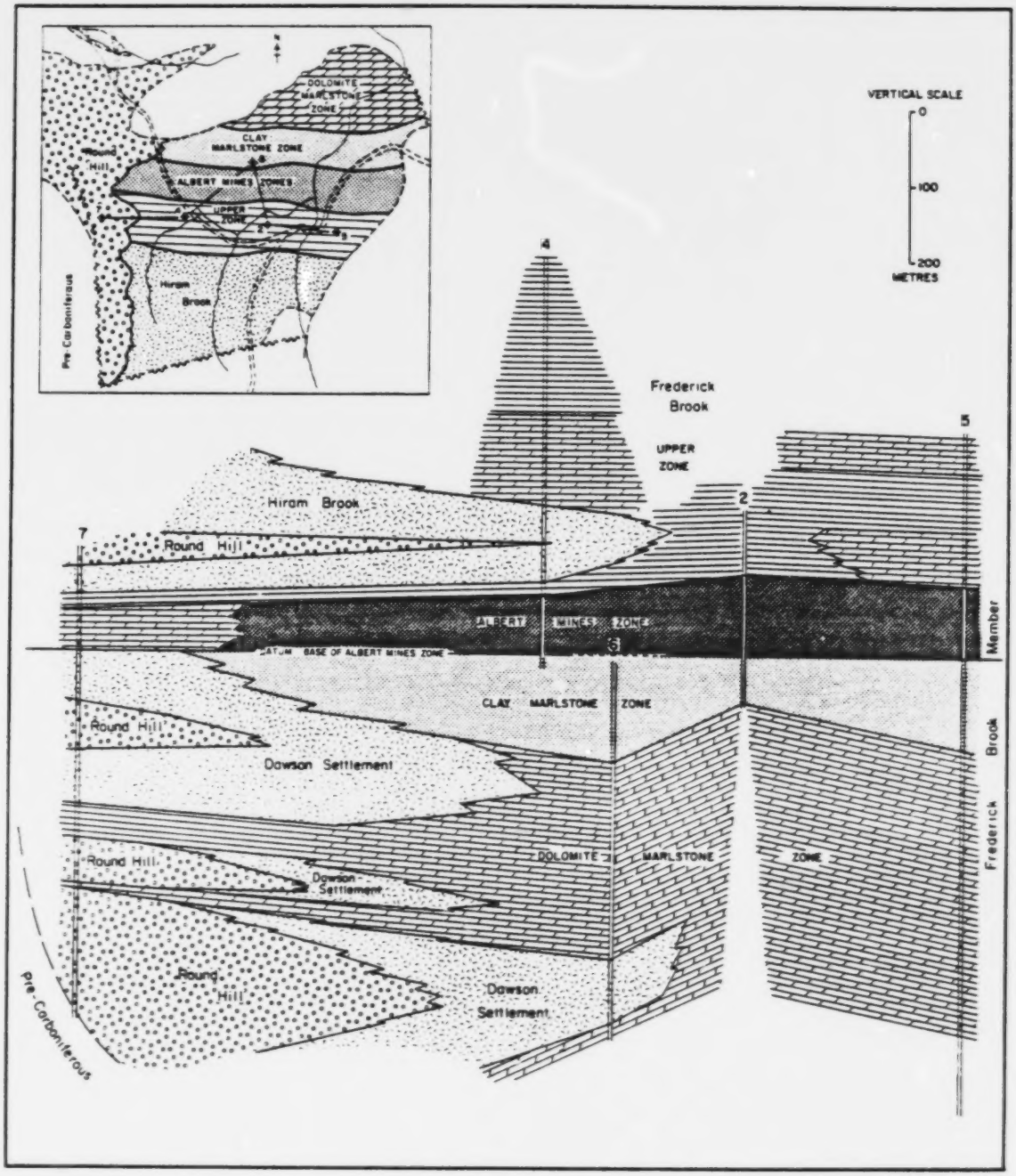


Figure 15: Lithologic correlation section, Albert Mines area

at the south and northeast. The southern contact of the Hiram Brook with the Hillsborough-Weldon (Moncton Group) appears conformable with Hiram Brook-Weldon possibly deposited as facies equivalents. The north-northwesterly relationship of red Hillsborough to grey Round Hill and to other Albert Formation members may be largely a facies change; however, the northeasterly change from lower Albert dolomite marlstone beds to Hillsborough is probably fault controlled.

Pennsylvanian Enrage Formation unconformably overlies Albert beds at the east of the study area: Frederick Brook beds are considered to extend easterly below the Enrage strata, which may extend considerably the area of oil shale potential.

The local structure of the Albert Formation at Albert Mines has been mapped with increasing complexity by successive geologists. Initially the feature was interpreted as a simple southwesterly plunging anticline with the crest along Frederick Brook. Wright (1922) more fully recognized the structural complexity when he mapped the surface and abandoned adits. His graphical reproduction of the underground bedding attitudes (Fig. 16), coupled with those determined from the core (Fig. 4) indicate major structural disruption. Exact locations for the tunnels (Fig. 16), which essentially traverse the Albert Mines zone, are difficult to transfer from older to present map bases. The reader is referred to Wright (1922) or Macauley (1982) for their general locations.

This disruption does not appear to have caused thickened section by repetition, but folding within the higher kerogen zones has structurally expanded the oil shale section. Overturned zones are mapped by Wright and are necessary to explain core dips at AtlanticRichfield Albert Mines 1A.

Because of the folding contortions, the specific surface dips, on which the initial anticlinal interpretation was

made, are not considered reliable data on which to base a gross structural analysis. Structure contours on the base of the Albert Mines zone (Fig. 15), as mapped from the core holes, indicate an east-west general strike with a southerly dip at a minimum 55° average. The undulations interpreted on this structural horizon indicate the presence of transverse north-south trending broad anticlinal and synclinal features.

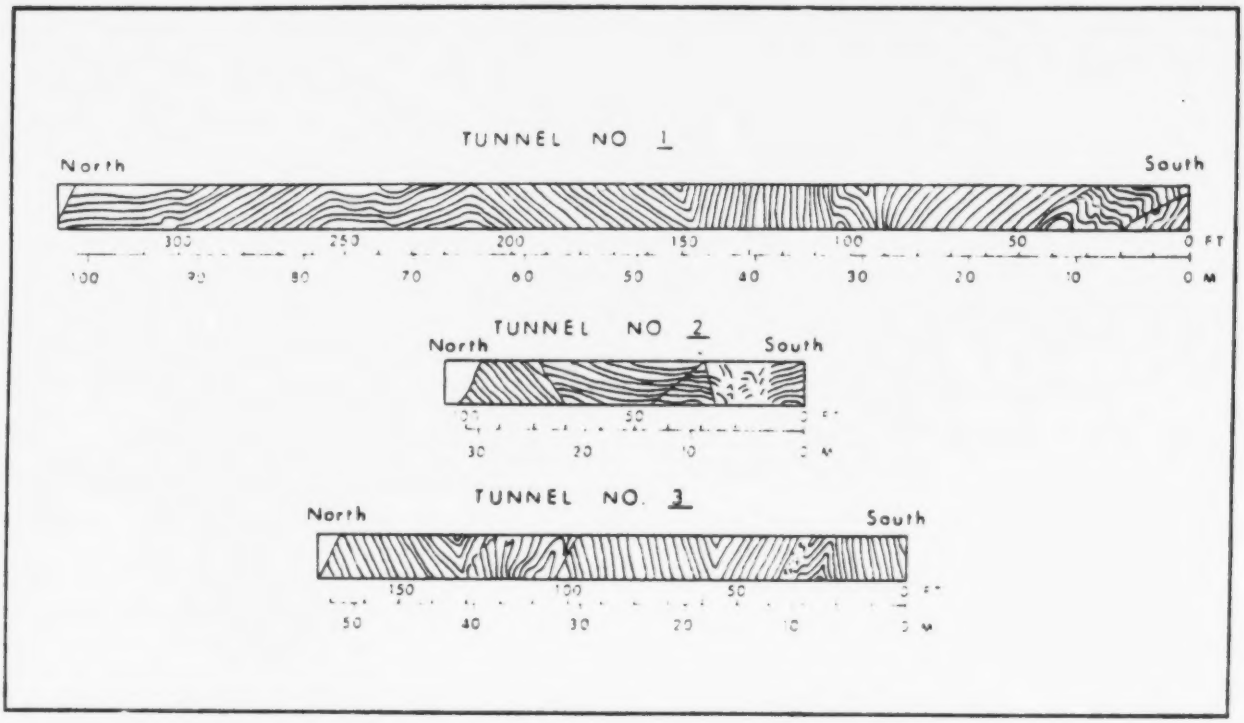


Figure 16: Structural attitudes of oil shale beds in tunnels at Albert Mines (after Wright, 1922)

Determination of true depositional thickness of the oil shales, particularly of the Albert Mines zone, along with minimum available core hole data, make volume estimates for oil shale reserves nebulous. Based on the dip characteristics encountered in the cores, and better estimates of thickness in the less disturbed Rosevale and Boudreau-Dover areas, 20 metres is possibly conservative and 30 metres not unrealistic as a depositional thickness for the Albert Mines zone. Given the

known folding of the zone, the depositional thickness may be expanded to a range of 60 to 100 metres thick across the surface outcrop belt. The degree of folding enhancement may decrease downward as interpreted from thinner Albert Mines zone at the deeper Can. Oxy. Albert Mines 4 core hole. The dolomite marlstone zone is not enlarged by folding and/or faulting.

At the surface, the Albert Mines zone appears to occupy a band approximately 100 metres wide by 1,500 metres east-west. Reducing the estimated width to 60 metres, so that structural deformation essentially doubles depositional thickness, and the length of 1200 metres for possible easterly development of the Round Hill facies in the subsurface, 114.6 x 10^6 tonnes of oil shale are contained to a depth of 600 metres. At an estimated 55° southerly dip, 600 metres drilled depth equates to 730 metres on the zone surface. At an average yield of 93.5 litres/tonne (Table 1), the Albert Mines zone contains estimated in situ shale oil reserves, based on Fischer assay values, of 10.71 x 10^6 cubic metres (67.35 million barrels).

Hole number:	4	6	2	1A	5	Average
Zone:			Yield (litres/tonne)			
Upper Albert Mines	80.5		42.5 108.8	20.0 74.4	43.4 110.3	35.3 93.5
Clay marlstone	10.3	64.7	33.7	38.6	44.8	38.4
Dolomite marlstone		63.0	60.6	50.5	52.1	56.4

Table 1: Average hydrocarbon yields from the lithologic sub-units of the Frederick Brook Member, Albert Mines area.

Similar calculations for the other sub-units of the Albert Mines area are presented in Table 2: 42.85 x 10^6 cubic metres (270 million barrels) in situ shale oil are estimated for this deposit. These estimates do not include postulated additional oil shale deposits beneath Enrage beds at the east, and make only minor allowance for the influx of Round Hill, Hiram Brook and

Dawson Settlement clastics into the oil shale environment at the west. An indicated easterly improvement in shale oil yields may also be significant to that unexplored area below Enrage beds.

Zone	Thick. m	Length m	Yield l/t	Density g/cc	Mass $t \cdot 10^6$	In Situ Reserves $m^3 \cdot 10^6$	$bbls \cdot 10^6$
Upper	75	1000	35.3	2.40	131.4	4.64	29.17
Albert Mines	60	1200	93.5	2.18	114.6	10.71	67.35
Clay marlst.	45	1200	38.4	2.37	93.4	3.59	22.56
Dolomite marlst.	180	1400	56.5	2.30	423.1	23.90	150.35
Total	360				762.5	42.84	269.43

Table 2: Estimated in situ reserves to a depth of 600 metres vertical (730 m on zone surface).

The gravities of the shale oil derived from the Albert Mines area average 0.872 (30.77°, API) and vary only slightly from one zone to the next, with those zones containing greater amounts of clay yielding slightly better quality oil. The average yield versus total organic carbon content of the area is 9.09 litre/tonne per 1% of organic carbon, varying from zone to zone directly with the degree of laminar development. The kerogen, as indicated in Figure 11a and born out by the production index, is very immature, the area having acted as a source for little if any hydrocarbons. No indication of humic content exists based on either the result of sample pyrolyses or core examination. The hydrogen and oxygen indices indicate that the same algal organisms resulted in the kerogen accummulations in each zone which subsequently underwent similar processes of development.

Boudreau

AtlanticRichfield Boudreau 1 (Fig. 5), near Boudreau Village (Fig. 2) on the east side of the Petiticodiac River,

was spudded in Hiram Brook Member. This core hole penetrated approximately 300 metres of typical Frederick Brook carbonates, mostly dolomite marlstone, underlain by a minimum 160 metres of Round Hill conglomerates with interbedded dolomite marlstones.

From surface mapping by McLeod and Ruitenberg (1978), the Albert Formation occurs along a southwest-northeast trend, with a north-dipping sequence conformably overlain by Weldon at the northwest, and overlain by Enrage Formation at the southeast with a fault contact (Fig. 17). The core hole structural data confirm this surface interpretation.

A proximal setting relative to a positive source area during time of deposition is indicated by the Round Hill conglomerates. Assuming the possibility of similar facies relationships here as at the Albert Mines area, better quantity and quality of oil shale may have been deposited in areas more distal to the local uplifted source. The direction of such improved deposits is open to speculation.

Shale oil yields are much less than at Albert Mines, with average recoveries as follows: upper zone, 6.7; Albert Mines zone, 28.4; clay marlstone zone, 13.8; dolomite marlstone, 35.2, all in litres/tonne. Because of almost barren intervals within each unit, these data obscure two significant zones with considerable yield in excess of 50 litres/tonne, one at the base of the Albert Mines zone and the second at the top of the dolomite marlstone zone (Fig. 5). Both higher yield intervals are of sufficient thickness to warrant exploratory interest.

The average yield versus total organic content is 8.40 litres/tonne per 1% of organic carbon, less than that at Albert Mines, indicating greater kerogen maturity. The kerogen is basically type I (Fig. 11c) although a few samples of possible types II and/or III are present. These latter are from the

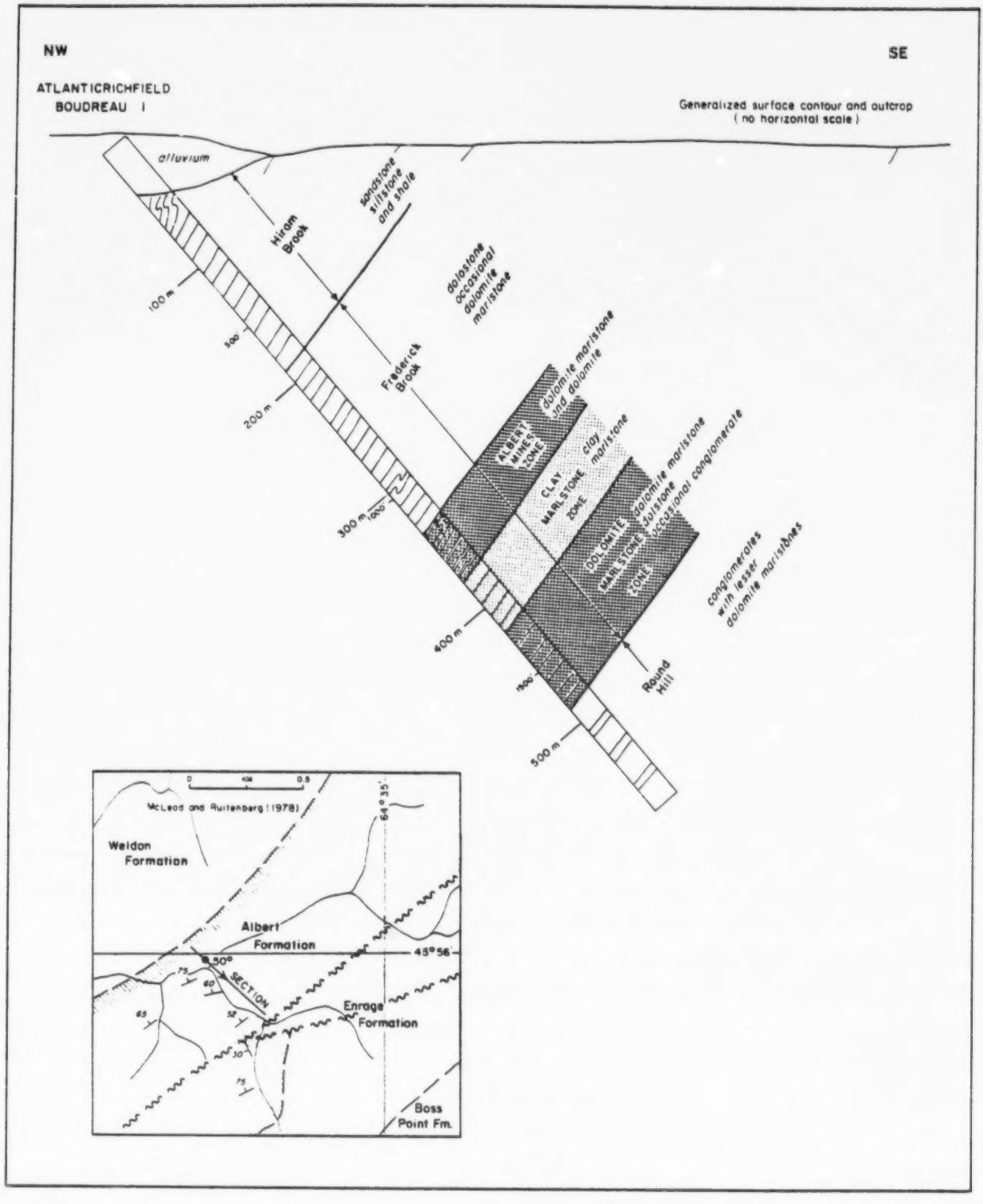


Figure 17: Structural interpretation, Boudreau area

Hiram Brook sandstones and the upper zone oil shales, both known to contain carbonaceous plant fragments. The hydrogen and oxygen indices indicate that the same algal organisms resulted in the kerogen as in the Albert Mines area which subsequently underwent similar processes of development.

Most of the Albert Mines zone is here represented by dolomite marlstone: laminated marlstones are not present. Zonal correlation is defined by the water yield of the clay marlstone zone, the distribution of the higher yield intervals, and the stratigraphic position of the oil shales between Hiram Brook and Round Hill facies.

Dover

AtlanticRichfield Dover 1A (Fig. 2) cored approximately 200 metres of Frederick Brook carbonate, mostly dolomite marlstone as at Boudreau, but with 30 metres of light brown to grey massive dolomitic shale within the dolomite marlstone zone. The hole bottomed in Dawson Settlement clastics in contrast to the coarser Round Hill conglomerates at Boudreau.

McLeod (1980) illustrates an east-west trending sequence, dipping southward at low angles, unconformably overlain by Enrage Formation. Core hole data are easily interpreted within this structural framework (Fig. 18).

Although finer grained than those of the equivalent Boudreau section, the presence of basal Dawson Settlement clastics, below an interpreted thin dolomite marlstone equivalent, can be used to draw similar conclusions *vis-a-vis* the Dover 1A core hole position relative to potentially better oil shale deposits.

Average yields from core data are low, averaging 17.8

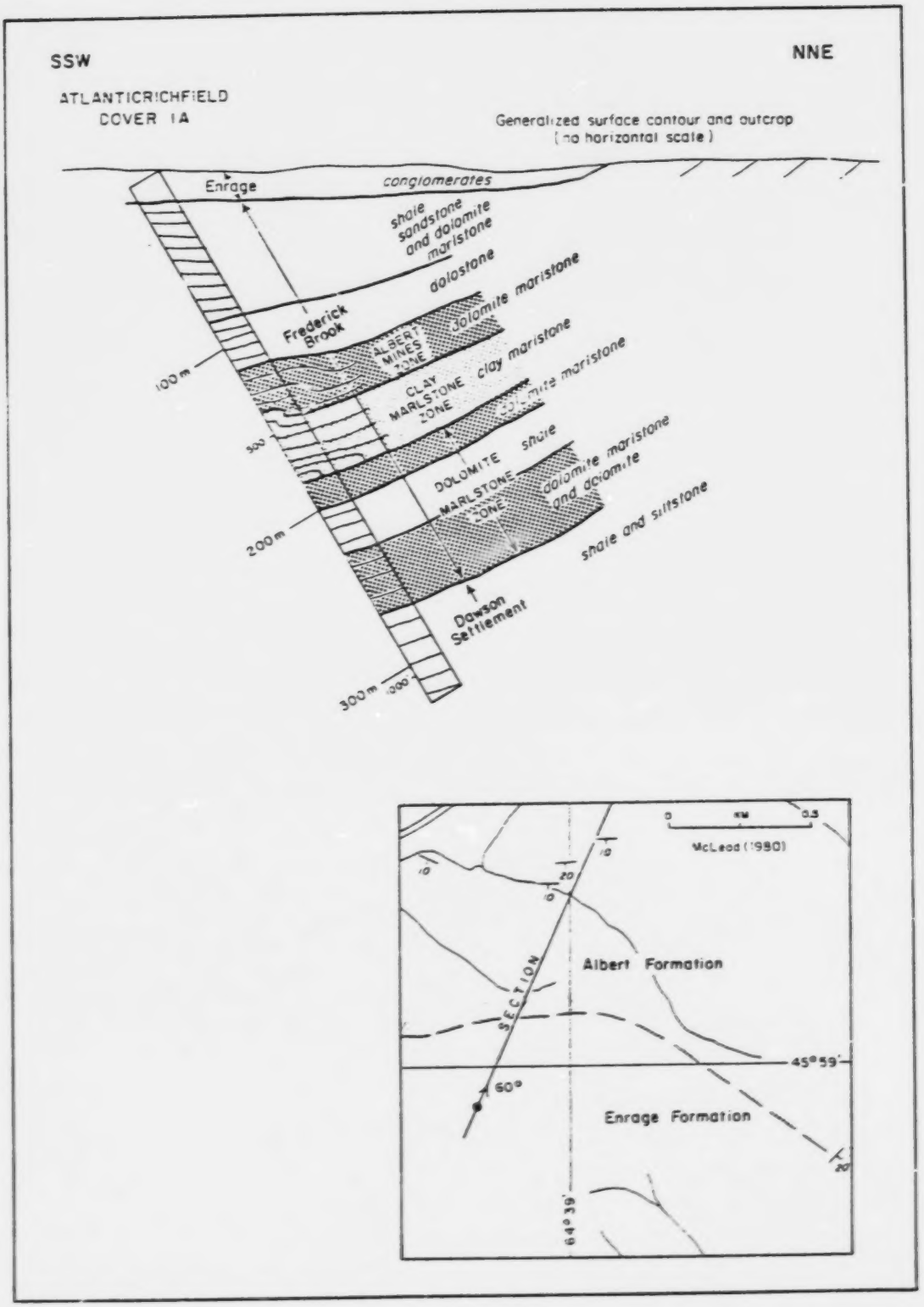


Figure 18: Structural interpretation, Dover area

(upper zone), 26.0 (Albert Mines zone), 8.6 (clay marlstone) and 17.0 (dolomitic marlstone) litres/tonne for the four zones; however, these averages again obscure two good zones exceeding 50 litres/tonne in the dolomite marlstone interval (Fig. 5). As was the case at Boudreau, the kerogen is basically type I (Fig. 11c) with a few samples of possible types II and/or III.

Rosevale

The AtlanticRichfield Company and Canadian Occidental Petroleum Company each drilled a core hole in the Rosevale area (Fig. 2). Lithologic logs of these holes (Fig. 5), in conjunction with surface data by Worth and Crosby (1975), have been used to construct a structural-stratigraphic section across the deposit (Fig. 19). Worth and Crosby indicated the Albert Formation, overlain by Hillsborough conglomerates, to be in fault contact with Precambrian volcanics of the Caledonia Uplift at the south; however, Ruitenberg *et al.* (1975) indicates onlap of the Albert sediments onto the Uplift.

At Rosevale, the Albert Formation crops out along a west-northwesterly trend, dipping gently northerly at about 35° (Fig. 19), but with dip apparently increasing at the south nearer the Caledonia Uplift.

AtlanticRichfield Rosevale 1 penetrated the entire Albert section, including Hiram Brook, Frederick Brook and the siltstone-sandstone beds and grey to brown dolomite shales of the Dawson Settlement. The thinner Hiram Brook section at the west is interpreted to be a facies thinning to equivalent Hillsborough (Moncton Group) conglomerate: the core contact of the red beds over the Hiram Brook at Can. Oxy. Rosevale 1 is conformable. A thick basal sandstone of the Hiram Brook almost directly overlies the Albert Mines zone as most of the upper zone of the Frederick Brook is missing due to facies

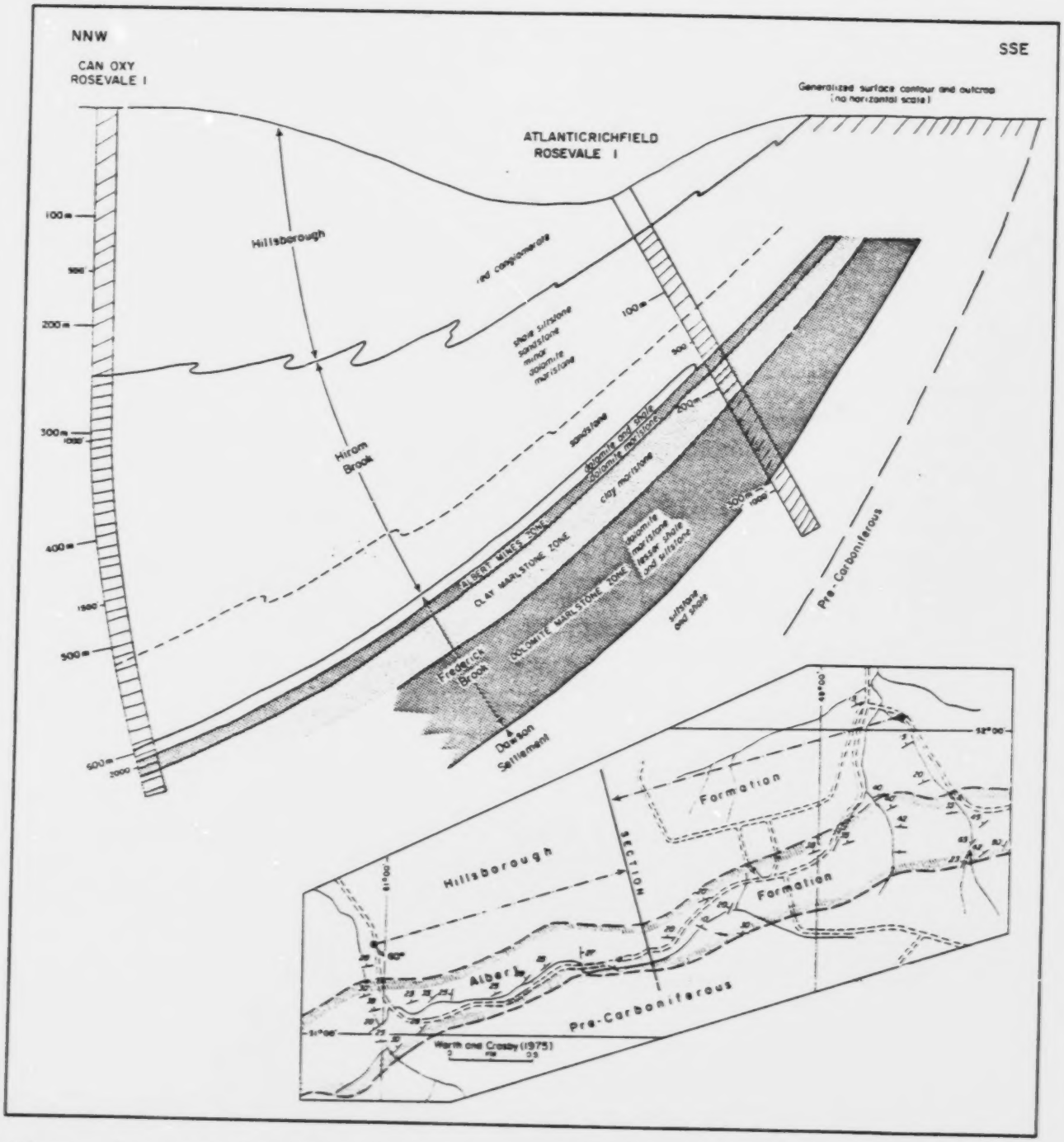


Figure 19: Correlation section with structural interpretation, Rosevale area

change.

Oil yields of Fischer assays in the Rosevale cores indicate low oil content: Table 3 summarizes hydrocarbon yields at this locality.

Zone	Can.Oxy. Rosevale 1	Alt.Rich. Rosevale 1	Average
	Yield (litres/tonne)		
Upper	10.4	25.9	18.2
Albert Mines	36.8	27.5	32.2
Clay marlstone	21.5	6.5	14.0
Dolomite marlstone	50.5	21.5	36.0

Table 3: Average hydrocarbon yields from the lithologic sub-units of the Frederick Brook Member, Rosevale area.

Although dolomite marlstone zone is indicated on the log of Can. Oxy. Rosevale 1 (Fig. 5), the lithology is mostly silty shale to siltstone and some sandstone. The good yield may in part be attributable to bitumen and/or kerogen within thin sandstone beds as the shales do not appear visually to contain significant kerogen.

Within the Albert Mines zone, a sub-zone 15 metres thick in part exceeds 50 litres/tonne, and is of sufficient thickness and content to be economically interesting. Similar thin higher yield sub-zones of the dolomite marlstone also warrant further investigation. Although not necessarily indicative of the entire area, organic carbon content is somewhat less and the degree of maturation somewhat greater at Rosevale than at Albert Mines.

Continuity of the oil shale zones of the Albert Formation along the northern border of the Caledonia Uplift from Rosevale to Albert Mines is possible, but is considered unlikely. Separation is anticipated by the distribution of the Round Hill

conglomerate facies, on the westerly flank of the Albert Mines deposits, projecting northerly to equivalent Hillsborough conglomerate of the Shenstone area.

Urney

Five test holes have been drilled into an anticline near Urney (Fig. 2), 11 kilometres east of Sussex, and the most westerly control data of this study. A core hole drilled by AtlanticRichfield was logged and sampled (Fig. 5): where available, additional geological and geophysical logs of the other holes were used to construct the stratigraphic-structural cross-section (Fig. 20) for this anticline. As the available lithologic logs of the drill holes did not correspond in emphasis to the "oil shale" direction of the core logs herein, especially in the nature of the carbonates and detail of the relative carbonate/clastic ratios, the zonations illustrated are very much interpretive.

In conjunction with drill hole data, the bedrock geology of McCutcheon (1980) indicates a sequence of Mississippian Albert Formation to Pennsylvanian Hopewell Group (Fig. 3) draped over a northeasterly plunging anticline (Fig. 20).

A great thickness of Albert Formation, in particular the Frederick Brook Member, was penetrated by United-Pan Canadian McLeod Brook 1 as a result of drilling down the dip on the west limb of the anticline. Hole deviation problems became maximum in the uppermost beds of the Frederick Brook Member. This hole terminated approximately 280 metres easterly of the surface location after having deflected 60 metres south at about the halfway point. Both the United-Pan Canadian and Kerr-McGee holes encountered known deviation problems: the Shell and New Brunswick Oilfields holes were probably also deflected by the structure, but deviation logs are not available.

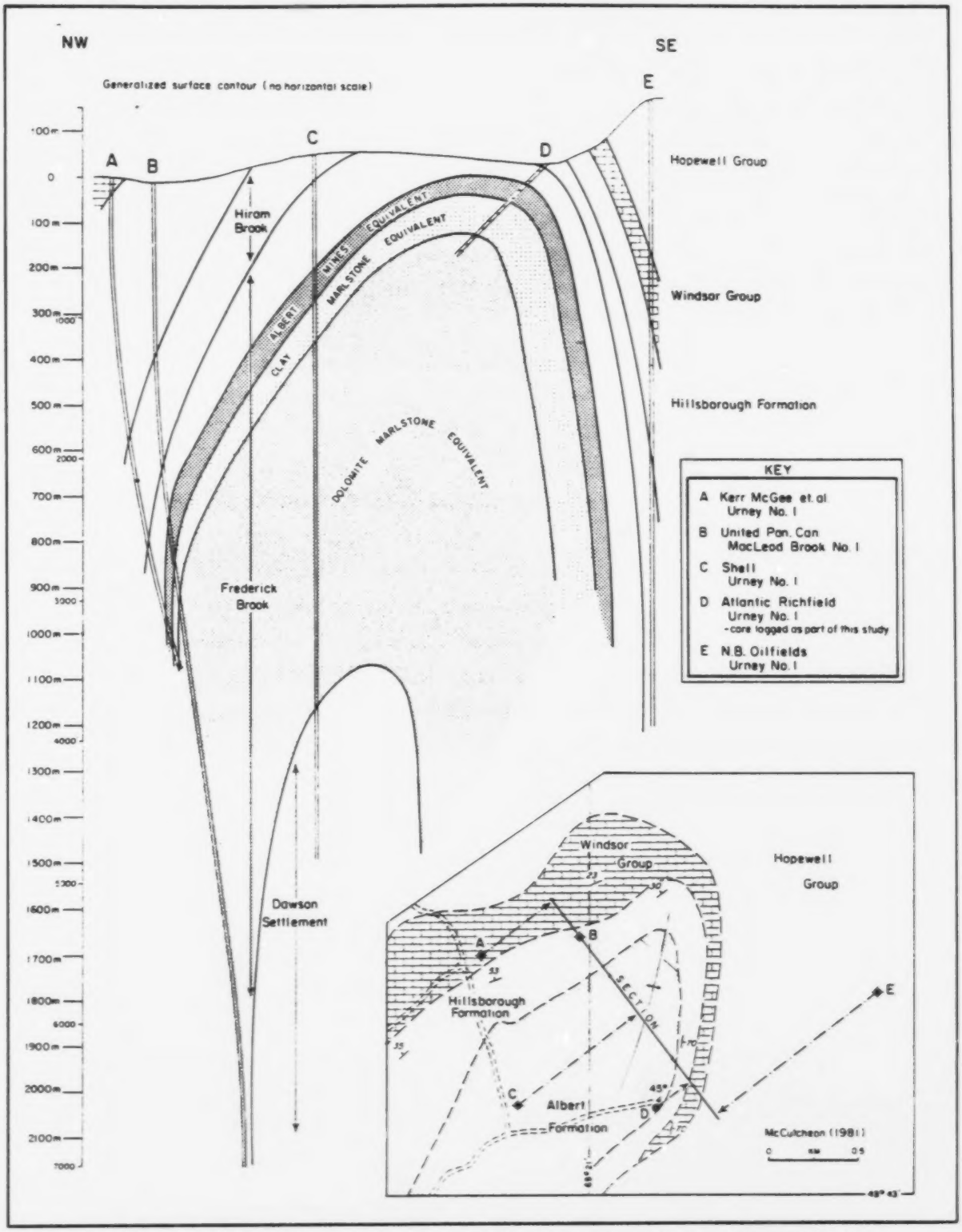


Figure 20: Correlation section with structural interpretation, Urney area

Although designed to penetrate a maximum stratigraphic section on the easterly flank of the anticline, the Atlantic-Richfield Urney 1 core hole is essentially following dip on the west flank of the anticline in dolomite marlstone beds at the bottom of the hole.

In addition to the exaggerated thicknesses because of hole deviation turning along the dip, the complexities logged at AtlanticRichfield Urney 1 indicate structural thickening similar to the fold-fault contortions of the Albert Mines area. Inter-laminae and interbed movement, promoted by kerogen laminae, are associated with the Urney anticline as are brecciated and slickensided zones.

Oil yield data are available from the AtlanticRichfield core hole. Recoveries were low at 6.5 (upper zone equivalent), 8.5 (Albert Mines equivalent), 5.1 (clay marlstone equivalent), and 10.1 (dolomite marlstone equivalent) litres/tonne. Only a thin interval of uppermost dolomite marlstone equivalent was penetrated; consequently, this zone is essentially untested. Total organic content values are the least of the areas evaluated, and a greater degree of maturation of the kerogen is also indicated.

SUMMARY

The Albert Formation is subdivided into a lower unit of sandstone, siltstone, shale and conglomerate, the Dawson Settlement Member; a medial unit of oil shale, limestone, calcareous shale and siltstone, the Frederick Brook Member; and and upper unit of siltstone, shale, calcareous sandstone and minor oil shale, the Hiram Brook Member. Although the Dawson Settlement Member includes little or no oil shales or argillaceous limestones, differentiation of the Dawson Settlement from the Hiram Brook is dependent upon recognition of the distinctive medial Frederick Brook Member. Grey polymictic conglomerates of the Round Hill Member are inter-zoned with all members of the Albert Formation. The relationships of the members of the Albert Formation, and between the Albert Formation and its bounding rock units are those of facies change. The red versus grey colour relationship must be utilized with caution, given the known oxidation/reduction reaction complications, to define sub-aerial versus sub-aqueous depositional environments rather than just a layered stratigraphic sequence.

The Frederick Brook Member is subdivided into four lithologic units. The three lower units, the dolomite marlstone, the clay marlstone and the Albert Mines zone, in ascending order, consist predominantly of dolomite marlstone, clay marlstone and laminated marlstone, respectively, The upper, upper zone, consists predominantly of shale, dolostone and dolomite marlstone. At Albert Mines recognition of the Albert Mines zone is assured by the high kerogen content; however, such recognition is not nearly so positive in areas where environmental conditions were not favourable to the concentrated accumulation of the algal material. Recognition of this subdivision rests primarily upon the distinction of the clay marlstone zone with its increased clay content and associated relatively high water content as indicated by Fischer assay results. These subdivisions tend to be markedly inter-

gradational.

Dolomite marlstone, laminated marlstone and clay marlstone are the three lithotypes which form the oil shale deposits of the Albert Formation. They are interlaminated, interbedded and intergradational and defined by variations of their three major components, dolomite, clay and kerogen. Quartz and feldspar modify the three primary lithotypes. Sandstones and conglomerates are present within the oil shale sequence but do not constitute oil shale deposits in themselves. The physical characteristics of the oil shales are dependent upon the physical characteristics and relative abundance of their components with the result that colour, density, fissility, hardness and resistence to weathering vary widely.

The quantitative distribution of quartz, clay, calcite and analcime defines a mutually related mineral group, which contrasts inversely to a second mutual group, dolomite, siderite and albite feldspar. These groups are each dominant to specific lithotypes. The former typifies the upper zone shales, the laminated marlstones of the Albert Mines zone and the clay marlstones, whereas the latter identifies the dolomite marlstone and dolostones. These groupings are controlled primarily by the geochemistry of the depositing environments.

The oil shales display numerous primary sedimentary and imposed diastrophic structures. Primary sedimentary structures include stratification, penecontemporaneous deformation features, soft sediment brecciation, convoluted laminae and sediment injection. Imposed diastrophic structures include brecciation, slickensides, crenulation and folding, faulting and fracture filling. These imposed structures predominate in the laminated marlstones, are somewhat diminished in the clay marstone and shale beds and are of only minor significance in the massive resistent dolomite marlstones and dolostones.

Some degree of structural over-riding in the Albert Mines area has resulted in repetition, representing an increase of the section beyond the depositional thickness, however, slippage along kerogen planes, although indicative of considerable deformation, does not represent significant repetition beyond a thickening of the section.

The relationship of the shale oil yield and oil shale density changes with the dolomite-clay ratio and kerogen content for each lithologic zone. Uniform sampling and more complex mathematical computation than was attempted should define more accurate relationships between the shale oil yield and oil shale density than the visual plots produced by this study. Upon the generation of this more refined data density logs will then be an excellent exploration-development tool for oil shales. Whether or not a single curve can be defined and applied to all zones should be part of future computer investigations.

At Albert Mines the high shale oil yield laminated marlstone of the Albert Mines zone are readily discernible on an oil yield plot. The other zones are not distinctly defined by yield alone although all zones appear to contain intervals of better and poorer average yield. A similar alteration of higher and lower yield intervals is evident at Boudreau-Dover and Rosevale-Urney. As many of the higher yield intervals in the Albert Mines and dolomite marlstone zones and their zonal equivalents approach, if not surpass economic significance, a closer inspection of sub-zones within the presently known lithologic subdivisions is essential to appropriate economic evaluation.

The high water yield of the clay marlstone zone provides the basis for the zonal definition of the Frederick Brook Member.

The relationship between organic carbon content and oil shale yields at Albert Mines average 8.67 litres/tonne per 1% organic carbon in any quantity range. The yield variation, which reflects the degree of laminar development, across the lithologic zones is never more than 12%. Insufficient data is available to properly assess lithologic zones in the other areas but the indication is that the yield figures are lower than those at Albert Mines.

The kerogen at Albert Mines, type I with a minimum oxygen content, is very immature and exhibits no indication of any significant humic content. At Boudreau-Dover the kerogen is basically a type I with a few samples of type II and/or III associated with carbonaceous plant debris. Maturation is slightly greater than at Albert Mines but less than at Rosevale. At Rosevale-Urney the kerogen is a type I with a slightly elevated oxygen content relative to Albert Mines. Maturation is higher than at either Albert Mines and Boudreau-Dover. The same organisms provided the base for the kerogen which underwent similar processes of diagenesis in each area and for each lithotype. An additional humic source of kerogen may be present locally in the upper zone or in local oil shale beds within the Hiram Brook facies.

The Rock-eval pyrolysis and Fischer assay techniques duplicate each other for average oil yield values. There is a direct relationship between organic carbon, Rock-eval pyrolyses and Fischer assay data.

The oil shale-like nature of the hydrocarbon content of the sandstones and conglomerates indicates a need for more study to determine the nature of the hydrocarbons associated with the sandstone-conglomerate facies within the oil shale sequence.

A figure of 42.84×10^6 cubic metres (270 million

barrels) in situ shale oil is estimated for the oil shales of Albert Mines. The unknown extent of the influx of the Round Hill, Hiram Brook and Dawson Settlement clastics from the west into the Frederick Brook carbonates and the extent to which the Frederick Brook oil shales improve by quality and quantity to the east beneath the Enrage Formation, are not fully taken into account in this figure and require further investigation. In the Boudreau-Dover area the location of better quantity and quality oil shales deposited in areas more distal to the local uplifted source than those drilled warrants further study. This does not necessarily imply large geographical distance, given the rapid facies changes noted at Albert Mines.

A number of specific recommendations relevant to oil shale exploration arise from this study. At Albert Mines judicial spotting of core holes will indicate to what extent the Albert Formation extends easterly beneath the Enrage Formation, to what extent the coarse clastics extend easterly from their source data to the west into the oil shales and to what extent the Albert Mines zone extends to the south beneath the Hiram Brook Member and upper zone. In the Boudreau and Dover area, exploration should be aimed at locating oil shales deposited in areas more distal to the local source of the coarse clastics intersected by the drilling completed to date. The examination of the Albert Formation throughout the Moncton subbasin should concentrate on the facies relationships noted. The examination of the Formation should include all post-Middle Devonian to pre-Windsor sediments and interpretation should take the tectonic elements affecting these sediments into account. Where possible, either through their present existence or through their future acquisition at the appropriate locations, the use of core holes and geophysical logs will prove a valuable addition to the properly recorded surface data. It is strongly suggested that all geological maps compiled in the future include the details of the facies relationships and not just the interpreted formational contacts.

REFERENCES

Bass, M. S., Bujak, J. P. and Williams, G. L.
1979: Palynological zonation and correlation of sixty-seven wells, eastern Canada; Geological Survey of Canada, Paper 78-24, 103 p.

Belt, E. S.
1968: Carboniferous continental sedimentation, Atlantic Provinces, Canada; Geological Society of America, Special Paper 106, pp. 127-176.

Berkeland, P. W.
1974: Pedology, weathering and geomorphological research; Oxford University Press, Toronto, pp. 59-64.

Berry, L. G. and Mason, B.
1959: Mineralogy; W. H. Freeman and Company, San Francisco, 630 p.

Espitalie, J., Madec, M., Tissot, B., Menning, J. J. and Leplat, P.
1977: Source rock characterization method for petroleum exploration; Proceedings 9th Annual Offshore Technology Conference, Houston, Texas, pp. 439-444.

Greiner, H. R.
1962: Facies and sedimentary environments of Albert shale, New Brunswick; Bulletin of the American Association of Petroleum Geologists, Vol. 46, No. 2, pp. 219-234.

Gussow, W. C.
1953: Carboniferous stratigraphy and structural geology of New Brunswick, Canada; Bulletin of the American Association of Petroleum Geologists, Vol. 37, No. 7, pp. 1713-1816.

Hacquebard, P. A.
1972: The Carboniferous of eastern Canada; Compte Rendu 7e, International Congress of Carboniferous Stratigraphy and Geology, pp. 69-90.

Hayes, A. O.
1927: Bituminous shales and other mineral occurrences in the vicinity of Sussex, New Brunswick; Geological Survey of Canada, Summary Report, 1925. Part C, pp. 125-127.

Howie, R. D.
1980: The Albert Formation, New Brunswick - deltas and oil shale; Geological Survey of Canada Open File Report 671.

Imperial Oil Ltd.
1960: Report on exploration conducted in New Brunswick during the year ending December 31, 1959; Unpublished Report on file at New Brunswick Department of Natural Resources, 15 p.

King, L. H.
1963: Origin of the Albert Mines oil shale (New Brunswick) and its associated albertite; Canada Department of Mines, Mines Branch Research Report R115, 24 p.

Macauley, G.
1982: Geology of the oil shale deposits of Canada; Geological Survey of Canada, Paper 81-25, *in press; also* Geological Survey of Canada, Open File Report OF754, 156 p.

McCutcheon, S. R.
1981: Stratigraphy and paleogeography of the Windsor Group in southern New Brunswick; New Brunswick Department of Natural Resources, Mineral Resources Open File Report 81-31, 210 p.

McLeod, M. J.
1980: Geology and mineral deposits of the Hillsborough area, map area V-22 and V-23; New Brunswick Department of Natural Resources, Mineral Resources Map Report 79-6, 35 p.

McLeod, M. J. and Ruitenberg, A. A.
1978: Geology and mineral deposits of the Dorchester area, map area W-22 and W-23; New Brunswick Department of Natural Resources, Mineral Resources Map Report 78-4, 27 p.

Morgenstern, N.
1967: Submarine slumping and the initiation of turbidity currents, *in* Marine Geotechnique, A. F. Richards, *editor*; University of Illinois Press, Urbana, Illinois, pp. 189-220.

Norman, G. W. H.
1932: Stratigraphy of the Stoney Creek oil and gas field, New Brunswick *in* Oil and Gas in eastern Canada; Geological Survey of Canada, Economic Geology Series No. 9, Report No. 2294, pp. 167-173.

Opik, I. and Kaganovitch, I.
1982: Oil shale of the Baltic Basin: power engineering and thermal processing; World Oil Shale Resources and their Potential Development, 6th IIASA Resource Conference, Golden, Colorado, pre-print.

Pickerill, R. K. and Carter, D.
1980: Sedimentary facies and depositional history of the Albert Formation; New Brunswick Department of Natural Resources, Mineral Resources Open File Report 80-3, 132 p.

Ruitenberg, A. A., Giles, P. S., Venugopal, D. V., Buttimer, S. M., McCutcheon, S. R. and Chandra, J.
1975: Geological maps *to accompany report* geology and mineral deposits, Caledonia area; New Brunswick Department of Natural Resources, and Canada Dept. of Regional Economic Expansion, Fredericton, N. B.

Schmitz, H. H.
1982: Oil-shale research and resources in Germany; World Oil Shale Resources and their Potential Development, 6th IIASA Resources Conference, Golden, Colorado, pre-print.

Worth, J. K.
1977: Oil shale and lithofacies, Albert Formation, Hillsborough sub-basin, New Brunswick; Canadian Occidental Petroleum Limited, Calgary.

Worth, J. K. and Crosby, K. S.
1975: Final report, Albert Formation oil shale mapping programme, Kings, Albert and Westmorland Counties, New Brunswick; unpublished report prepared for Canadian Occidental Petroleum Limited, Calgary, available at New Brunswick Department of Natural Resources Mineral Resources Branch, Fredericton, N. B.

Wright, W. J.
1922: Preliminary report on the geology of the Moncton map-area; Geological Survey of Canada, Memoir 129, p. 1-50.

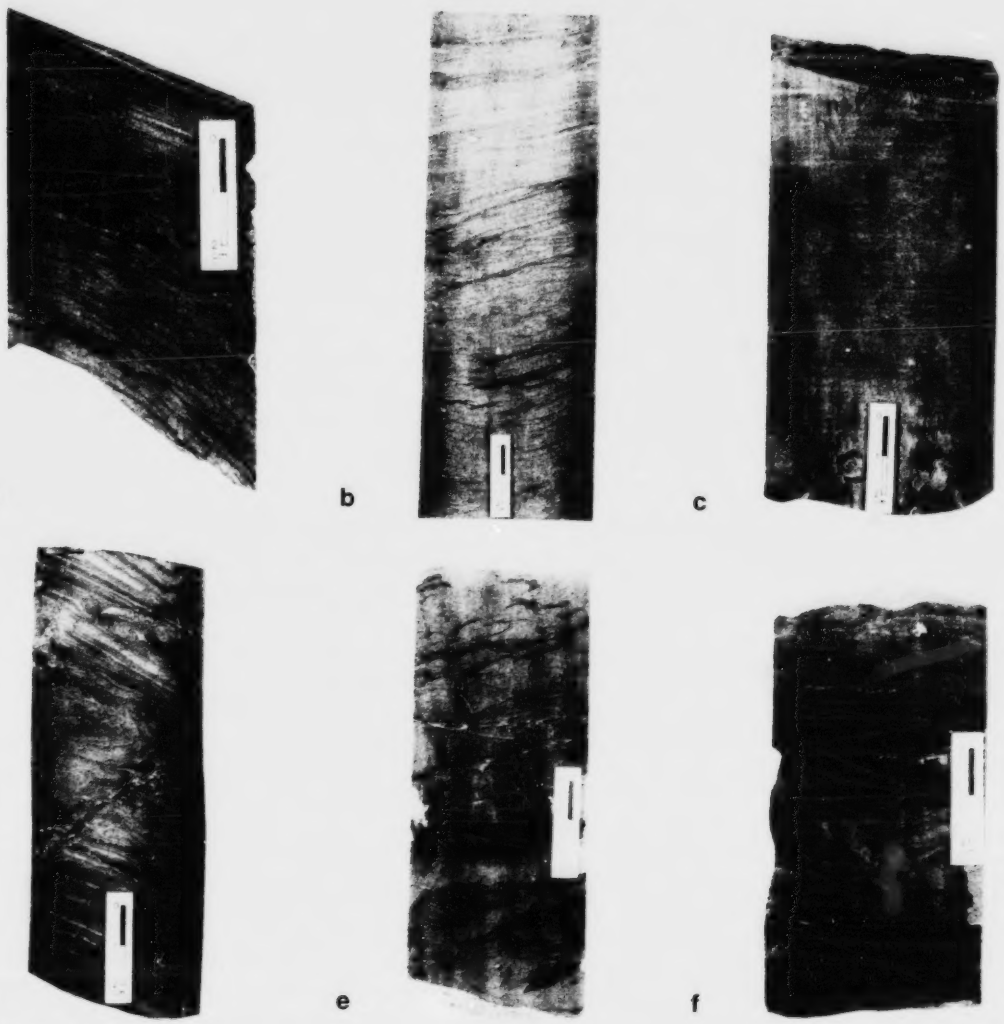


Plate 1.a: Atl.Rich. Boudreau 1, 300.2m(985'): discontinuous organic laminae in a dolomitic marlstone; upper shale z. - Fred.Brk.M.

b: Can.Oxy.A.M. 6, 327.4m(1074'): discontinuous organic laminae grading up to continuous fine laminae in a dolomitic marlstone; dolomite marlstone z. - Fred.Brk.M.

c: Can.Oxy.A.M. 6, 330.1m(1083'): massive silty dolomitic marlstone; dolomite marlstone z. - Fred.Brk.M.

d: Atl.Rich.A.M. 1A, 348.7m(1144'): continuous organic laminae in a dolomitic marlstone displaying penecontemporaneous deformation structures including load and slump structures and soft sediment brecciation; dolomite marlstone z. - Fred.Brk.M.

e: Atl.Rich.A.M. 1A, 483.1m(1585'): discontinuous organic laminae in a silty dolostone displaying "rip-up" breccia and load structures; dolomite marlstone z. - Fred.Brk.M.

f: Atl.Rich.A.M. 1A, 303.3m(995'): discontinuous organic laminae in a dolomitic marlstone displaying load structures in the form of pseudonodules; dolomite marlstone z. - Fred.Brk.M.

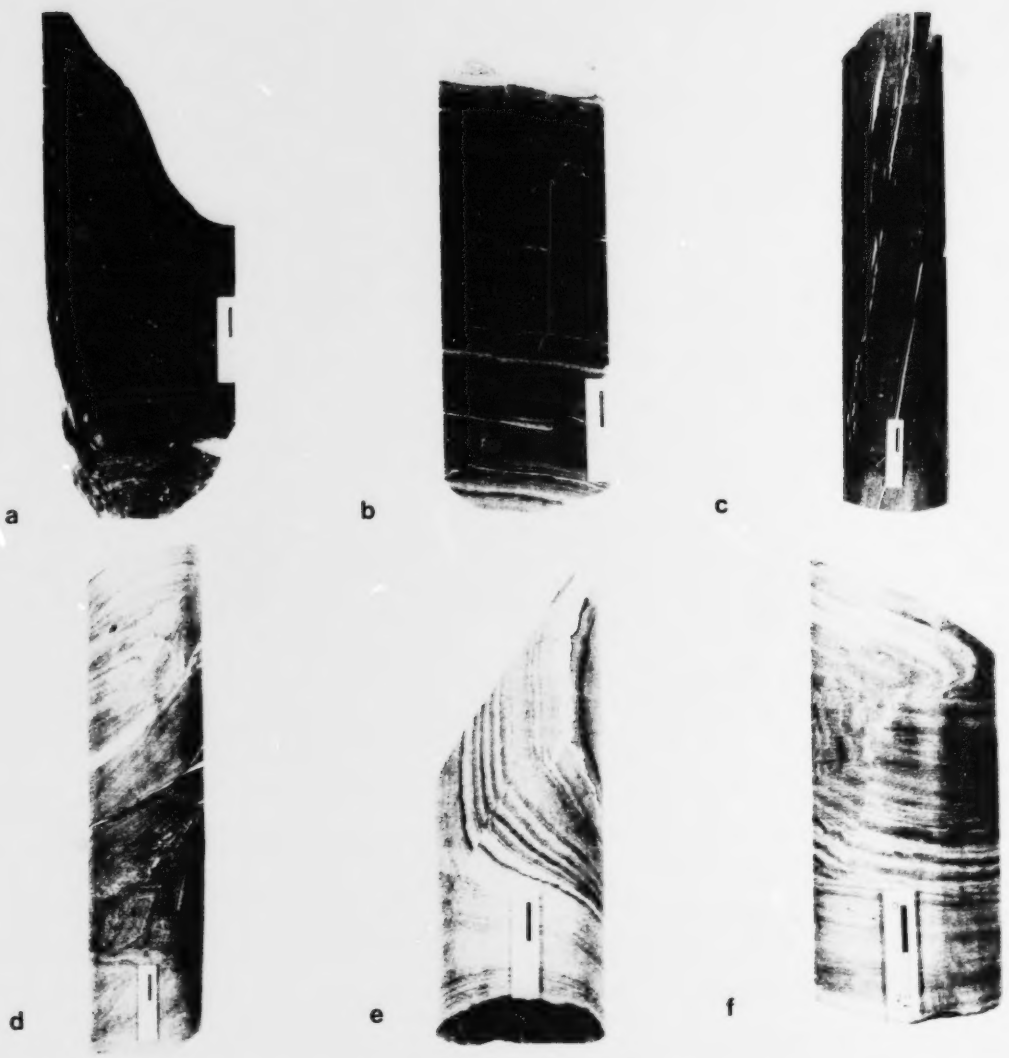


Plate 2.a: Can.Oxy.A.M. 7, 119.5m(392'): deformed bedding, due to folding of a laminated dolomitic marlstone; Albert Mines z. - Fred.Brk.M.

b: Atl.Rich.A.M. 1A, 11.6m(38'); fissile, organically laminated (varved) dolomitic marlstone; upper shale z. - Fred.Brk.M.

c: Can. Oxy. A.M. 2, 157.6m(517'): calcite stringers parallel to high angle bedding in a laminated dolomitic marlstone; Albert Mines z. - Fred.Brk.M.

d: Can.Oxy.A.M. 2, 176.2m(578'): calcite stringers in a laminated dolomitic marlstone displaying both penecontemporaneous and structural deformation features; Albert Mines z. - Fred.Brk.M.

e: Can.Oxy.A.M. 2, 174.0m(571'): calcite stringers in a bedded to laminated dolomitic marlstone displaying deformed bedding; Albert Mines z. - Fred.Brk.M.

f: Atl.Rich. Boudreau 1, 312.7m(1026'): deformed and brecciated bedding of a bedded to laminated dolomitic marlstone; upper shale z. - Fred.Brk.M.

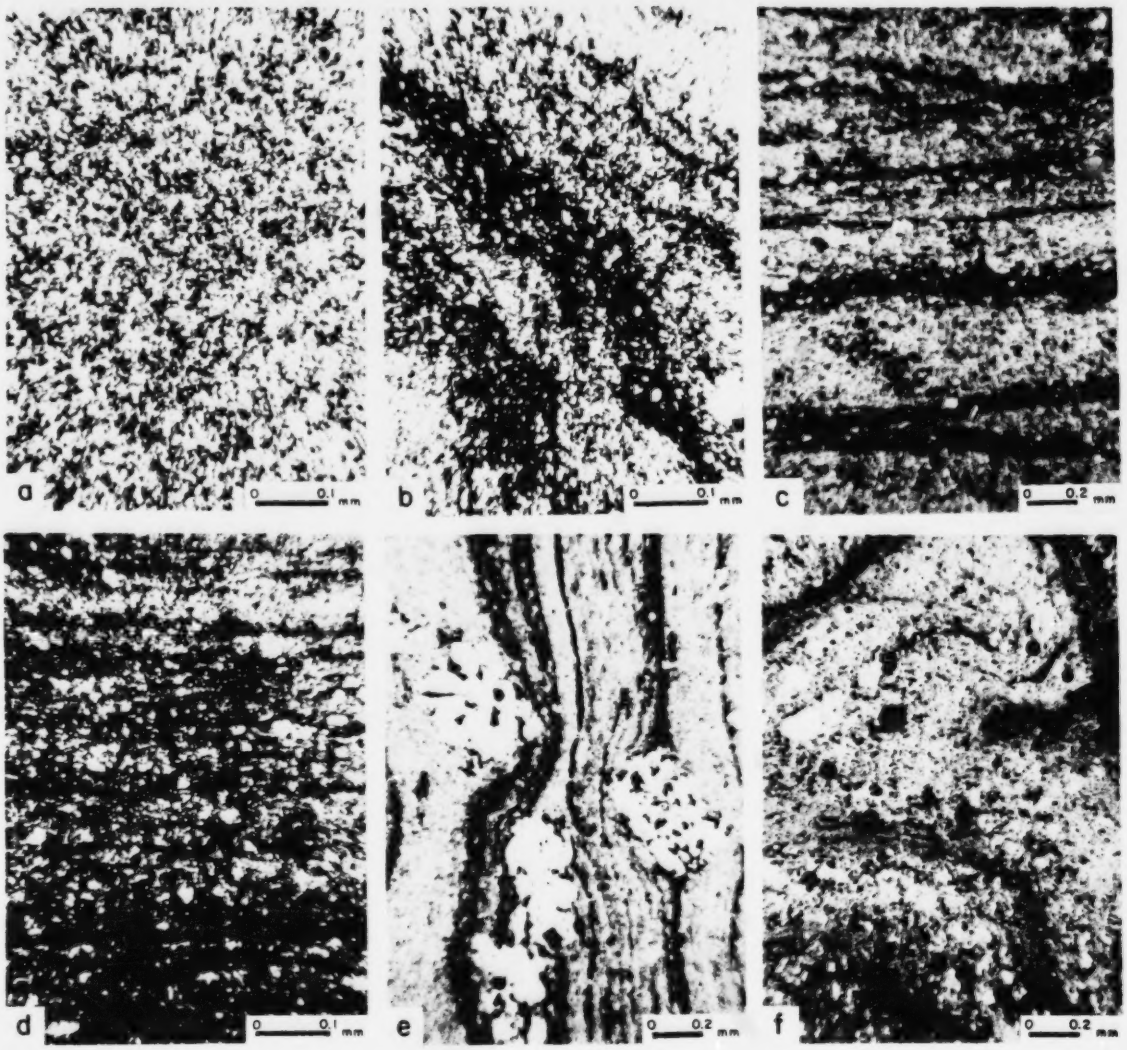


Plate 3.a: Atl.Rich.A.M. 1A, 483.1m(1585')(p.p.l.): minor "flecks" of organic material (black, elongate) and quartz grains (white, equidimensional) in a carbonate ground mass of a silty dolostone; dolomite marlstone z. - Fred.Brk.M.

b: Atl.Rich.A.M. 1A, 483.1m(1585')(p.p.l.): organic laminae (dark grey) of a "rip-up" clast in a silty dolostone; dolomite marlstone z. - Fred.Brk.M.

c: Atl.Rich. Boudreau 1, 300.2m(985')(p.p.l.): discrete organic laminae (dark grey) in a dolomitic marlstone; upper shale zone - Fred.Brk.M.

d: Atl.Rich.A.M. 1A, 11.6m(38')(p.p.l.): organic material forming both matrix, with carbonates and laminae in varved dolomitic marlstone; upper shale z. - Fred.Brk.M.

e: Can.Oxy.A.M. 6, 330.1m(1083')(p.p.l.): organic laminae disrupted and distorted by quartz grains in a silty dolomitic marlstone; dolomite marlstone z. - Fred.Brk.M.

f: Can.Oxy.A.M. 2, 176.2m(578')(p.p.l.): deformed bedding displayed by oriented organic "flecks" (black, elongate) and laminae of varying quantity of organic content (light to dark grey); Albert Mines z. - Fred.Brk.M.

APPENDIX 1

CORE DESCRIPTIONS

AtlanticRichfield Albert Mines 1A

30° off vertical towards N70°E (true)
elevation: 108.2 m

3.0-8.2 m (10-27'); siltstone, dark brownish-grey; laminated with slightly variable silt-dolomite content; discontinuous organic flecks; in part organics within the dolomite matrix

8.2-12.8 m (27-42'); marlstone, brown; grading downward with much silt at top decreasing downward as organic lamination and banding increases; becomes in part varved in basal 2.4 m zone; light weight; slightly fissile; smokes extremely well, even in fairly thick edge

12.8-66.4 m (42-218'); shale, medium grey; slight brownish tinge, only very slightly dolomitic; chunky to some sub-fissile; several slickensided zones; 18.3-20.1 m - scattered bands of marlstone, very thin overlying and underlying sandstone lenses with some marlstone bands; 28.0-29.0 m - marlstone zone; 31.7 m and 32.6 m - greyish-brown hard massive, dolomitic siltstone bands; 49.4-50.9 m fault zone (?); 51.8-53.3 m - sandy, dolomite marlstone zones; 55.5-57.6 m - marlstone beds; 57.6-60.7 m - extreme slickensides; fault zone (?); 61.0-62.8 m - zones of brown massive silty dolomite; 61.0-66.4 m - badly rubbled, extreme slickenside, fault (?)

66.4-70.1 m (218-230'); dolomite, medium brown; 40% very fine quartz silt; flecks of organic material produce faint laminae; hard; massive

70.1-75.6 m (230-248'); marlstone; laminated to banded brown; in part dolomite bands are silty; not fissile; massive sandy marlstone type; quality decreases downward as clay increases, 73.2-75.6 m

75.6-79.2 m (248-260'); shale, brownish-grey; slightly dolomitic; chunky; only slight fissility noted

79.2-84.7 m (260-288'); marlstone, brown; silty; laminated; banded with sandy dolomite zones; some dark brown dolomitic siltstone to silty dolomite bands

84.7-88.4 m (288-290'); shale, brownish-grey; massive; silty; dolomitic

88.4-93.3 m (290-306'); marlstone, brown; finely laminated, some almost varved; mostly hard; no fissility except for thin

zone slickensided; very light weight zone at 90.8 m; slickensides at 91.4 and 92.0 m; zone of dense hard massive dolomite marl without significant laminae at 90.2-90.8 m; sandy and silty with thin beds light grey calcareous sandstone in top 2.4 m; slickensided zones approach papery type but basically all sandy marlstone

93.3-95.7 m (306-314'); siltstone, light brown, quartzose; massive; dolomitic; argillaceous; grades down to shale

95.7-103.3 m (314-339'); shale, medium brownish-grey; climbing to laminated; sub-fissile; dolomitic; zones of varved silty marlstone with fair to poor organic laminae and associated light grey sandstone laminae to beds; numerous glossy slickensides at 100.6-102.4 m mostly on bedding planes, definitely indicators of movement, but no rubble; rubbled, but no slickensides at 101.2 m to 103.3 m

103.3-108.5 m (339-356'); siltstone, brownish-grey, quartzose, argillaceous, dolomitic; massive; only faint discontinuous kerogen along indistinct bedding laminae

108.5-111.6 m (356-366'); marlstone, light brown to greyish-brown; silty; argillaceous; poorly laminated; minor fissility, apparently on argillaceous planes; in part grades to dolomitic massive siltstone and some shale laminae to beds

111.6-118.0 m (366-387'); marlstone, brown; laminated; in part sandy to silty; slickensided throughout along slightly warped laminae

118.0-125.6 m (387-412'); marlstone; laminated; varved; only scattered sandy laminae; fair oil shale but not as good as papery zones; a high grade of massive dolomite zone; not easily split even though a few slickensided surfaces are present

125.6-126.2 m (412-414'); sandstone, brown, dolomitic; massive; hard; could be massive sandy dolomite in places

126.2-140.8 m (414-462'); marlstone brown; laminated to varved in part sub-fissile; mostly massive; numerous thin bands to laminae of white quartzose calcareous sandstone; in part silty to sandy; becomes better grade and lighter weight downward; 122.5-125.0 m - numerous slickensided bedding planes; 132.6-132.9 m - slickensides

140.8-142.3 m (462-467'); shale, greyish-brown; chunky; rubbled; slickensided

142.3-154.5 m (467-507'); marlstone, brown; laminated; silty; basal 2.4 m with excellent brown lamination

154.5-156.7 m (507-514'); marlstone, greyish-brown; argillaceous content increases, slightly; silty; laminated; fissility on clay laminae; kerogen laminae still evident but decreased from above; some carbonaceous debris

156.7-157.3 m (514-516'); siltstone, medium greyish-brown; massive; argillaceous; dolomitic; carbonaceous debris

157.3-174.7 m (516-573'); marlstone, brown; laminated; silty, grading to marly siltstone; laminae increasing downward as marl content increases to 164.6 m then decreases to base of zone, some massive dolomite near base; 159.1-160.6 m - abundance of slickensides; 160.3-161.5 m - closely spaced kerogen laminae

174.7-180.4 m (573-593'); siltstone and dolomite; greyish-brown dolomitic siltstone to brown silty dolomite; massive to poorly laminated; 175.3 m - quartz fracture infill

180.4-184.7 m (593-606'); marlstone, laminae of light to medium-brown; banded to laminated; silty to sandy and grading to siltstone; numerous thin bands and laminae light grey fine grained quartzose sandstone; some organic laminae and abundant organic rocks throughout

184.7-188.1 m (606-617'); marlstone, medium brown; very finely laminated to varved; papery; silty; scattered very fine light grey quartzose sandstone laminae to very thin beds, not much less than zone above; albertite on bedding plane at 185.3 m

188.1-188.7 m (617-619'); marlstone; as above but with zones of light brown massive silty clean dolomite; no kerogen laminae and very few flecks

188.7-192.3 m (619-631'); marlstone, medium brown; very finely laminated, varved with abundance of continuous kerogen laminae; silty

192.3-193.5 m (631-635'); dolomite, very light brown; massive to faint laminae formed by discontinuous kerogen; silty, with zone grading to silty marlstone and zone of light brown fine grained dolomitic quartz sandstone

193.5-198.1 m (635-650'); marlstone, brown; silty; laminated; grading to numerous silty zones; a few thin bands of light grey sandstone becoming less distinct in bedding downward as the zone becomes more massive and kerogen grades to flecks rather than laminae

198.1-203.0 m (650-666'); sandy dolomite to dolomitic sandstone; massive to faint laminae; minimal discontinuous organic laminae to flecks; 0.3 m grey rubbled shale at 203.9 m

203.0-230.7 m (666-757'); shale, medium greyish-brown; slightly dolomitic; in part silty; laminated, in part sub-fissile; much rubbled; some slickensides; 209.4-210.3 m - several thin zones of light brown silty dolomite, massive, kerogen flecks, thin beds of quartz on bedding planes (post deposition); 214.3 m - scattered zones with thin alternating bands of light grey sandstone, inter-laminated sandy dolomite below 216.4 m; shale slightly browner in colour below 213.3 m relating to generally higher kerogen content; zones grading to argillaceous dolomite; increased slickensides and rubble at 216.4-230.7 m

230.7-233.5 m (757-766'); marlstone to dolomite; brown; fair to some good dark brown kerogen laminae; slightly silty; argillaceous

233.5-239.6 m (766-786'); shale, greyish-brown, dolomitic; laminated; in part fissile; scattered dolomite beds to laminae; silty marlstone zones in basal 0.6 m of interval

239.6-248.1 m (786-814'); marlstone to silty dolomite; brown, massive to poorly laminated; marlstone also silty; albertite veins 246.3-247.5 m cut across the bedding

248.1-249.3 m (814-818'); shale, brown, dolomitic, laminated; sub-fissile; slickensided; thin sandstone interbedded

249.3-250.2 m (819-821'); marlstone, silty; some zones good laminae; in part with sandy laminae and grading to silty-sandy dolomite

250.2-257.9 m (821-846'); marlstone, brown, argillaceous; some clay laminae and dolomitic shale interbeds; silty throughout; variable kerogen laminae development; some of shale is slickensided; 250.5-253.6 m - in part rubbled and slickensided

257.9-259.1 m (846-850'); shale; brownish-grey to brown; slightly dolomitic; rubbled; slickensided

259.1-262.1 m (850-856'); marlstone; laminated light to dark brown; very silty; dolomitic; good kerogen laminae to finely varved; not fissile

262.1-276.1 m (860-906'); dolomite, light brown; massive to some zones with poorly developed kerogen laminae; silty and in part possibly a dolomitic siltstone; a few scattered laminae of dolomite shale which has incrustation of white mineral and apparent brownish-black grains of albertite (or carbonaceous debris); these zones are contorted and rubbled, may indicate some movement

276.1-299.3 m (906-982'); marlstone; laminated brown; varved; extremely silty; zones grading to siltstone and patches

of sandstone; in part with very finely varved kerogen; occasional sedimentary slump texture

299.3-353.6 m (982-1160'); dolomite; light to medium brown; silty; alternating zones of clear dolomite and zones of marlstone with some fair to good organic lamination; silty throughout; dolomite zones have solution textures creating irregular organic partings causing a "boudinage" type texture; some differential compaction around sand pods and patches; sand not present as good bands or laminae; generally somewhat argillaceous; better assay results relate to sporadic zones of kerogen laminated marlstone within the gross interval, these zones smoke readily; silt decreases below 309.4 m but remains slightly silty; sand decreases but reappears by 329.2 m as does silt content; becomes quite silty in places and could be dolomitic siltstone; zone noted by silt content; solution textures and depositional slump fractures; some possible dessication structures; 346.3-351.1 m - numerous zones with abundant organic laminae, slump textures, solution breccia, slump breccia

353.6-389.5 m (1160-1278'); sandy dolomite to dolomite sandstone; massive to faintly bedded; variable quartz content; hard; rip-up clasts; solution textures; scattered kerogen flecks to very poor laminae; in part grades to zones of medium grey-brown dolomitic siltstone; several zones of silty sandy marlstone which have quartz grains concentrated in burrows; some zones show good laminae by alternating sandstones and silty dolomite; 378.0-390.0 m - increasing number of zones of 5 cm thick with good kerogen lamination; very silty; sand content decreasing, sand layers disappear downward

389.5-390.8 m (1278-1282'); marlstone, dark brown; very silty; kerogen disseminated throughout, but zone not laminated; may approach marly siltstone; light weight rock; will not split to thin edge, but smokes on heating

390.8-402.3 m (1282-1320'); silty marlstone, light brown; faint kerogen laminae; otherwise fairly massive; in part may be called a dolomitic siltstone; 399.0-399.6 m - zone of fine to medium grained quartz sand influx with rip-up clasts

402.3-406.0 m (1320-1332'); silty marlstone; darker brown as kerogen content increases; zones and irregular patches with distinct kerogen laminae; some possible rip-up in dessication clasts of the laminated material; depositional slump texture at 405.1 m

406.0-434.0 m (1332-1424'); marly siltstone to sandstone, light to medium brown; massive to some indicated lamination by occasional organic content, some thin zones with closely spaced kerogen laminae; often involved in rip-up clasts; sedimentary slump textures in the sand; some of the sand

seems to contain very finely disseminated organic flecks; probably argillaceous, may have oil content rather than all kerogen; at 410.9 m and 411.5 m slightly rubbled softer zones with white mineral deposit and albertite deposited rubble surfaces; some colour banding of light to darker brown and some greyish tinge rubbles to sand-silt-dolomite variations and occasionally to kerogen values; only scattered zones with significant kerogen lamination; occasional pressure solution fractures in the dolomitic intervals

434.0-435.3 m (1424-1428'); silty marlstone, medium brown; some fine kerogen lamination; sub-fissile with smooth breakage on kerogen planes

435.3-448.7 m (1428-1472'); silty marlstone, brown to brownish-grey; hard; generally massive; occasional faintly defined kerogen laminae; silty throughout; albertite in fractures at 437.4, 483.3, 438.6, 445.9 and 447.8 m silty and rubbled; can be ignited; not brittle; albertite in fractures at 447.9 m occurs in low assay zone, no reason to anticipate low yield

448.7-451.1 m (1472-1480'); marlstone, brown, silty; closely spaced kerogen laminae in zone with high assay values; solution textures from depositional compaction

451.1-475.5 m (1480-1560'); silty marlstone, brown; silty throughout; variable kerogen lamination; abundant organic concentration in pressure solution breccias and slump zone; numerous zones of rip-up breccia; lamination material contains kerogen and non-laminated in massive light brown silty dolomite; laminated material forms much of the rip-up breccia material and is often associated with the pressure solution textures with organic solution partings

475.5-492.6 m (1560-1616'); marlstone, brown, silty (slightly less than above); with irregular small elongate lenses; dark grey-brown siltstone; some discontinuous laminae in irregular patches which are darker brown and kerogen-bearing; rip-up breccias associated with the kerogen types; probably some fine kerogen grains in the main silty dolomite groundmass; laminated kerogen type decreases significantly below 484.6 m

492.6-515.1 m (1616-1690'); silty, marlstone, light to dark brown; banded and laminated with fair kerogen lamination; generally continuous; some sandy zones; amounts of laminated type varies throughout the interval and is mixed with more massive brown silty dolomite; some cross-lamination, solution textures and brecciation but much less than in zone above; some sand zones scattered through the interval; 510.2-511.5 m - extremely silty grading to dolomitic siltstones, dark grey-brown, massive, faint organic laminae; 361.5-

362.7 m - increasing kerogen laminae, solution partings and textures; much of the silty marlstone below the Albert Mines zone may be siliceous as well as silty, especially toward the bottom of the hole

515.1 m (1690'); T.D.

Canadian Occidental Petroleum Albert Mines 2

vertical
elevation: 103.6 m

10.7-85.6 m (35-281'); marlstone, dark greyish-brown, dolomitic; slight burning odor but no smoke or iginition; finely laminated; rubbles easily; poor oil shale quality; structurally disturbed in a series of imbricated faults; numerous slickensides occurring mostly along bedding planes but occasionally across the bedding; dolomite reaction is variable but decreases as kerogen content increases by comparison to assay values; the better zones will smoke and flow red when heated; no oil odor on breaking as the pieces are too rubbled and small to be able to open a new surface area of any size; core badly rubbled and split in core boxes; 17.0 m - thin 7.6 cm medium yellow-brown very dolomitic claystone band, this band is much thinner than indicated by the total peak area on the density log; 38.4 m - 20.3 cm dark yellow-brown dolomite band with 85° dip, this probably represents 5 cm of net zone; 42.1 m and 43.0 m - 10 cm dolomite bands, 60° dip; 50.3 m - irregular white calcite veinlets and braided bands crossing fracture zones, one band 2.5 cm thick parallel to bedding; 40° dip; 52.4 m and 53.6 m - 10 cm dolomite bands; 52.4-53.3 m - 0.6-1.3 cm lime veinlets parallel to bedding; 54.9-61.0 m - good drag folds, calcite veinlets in better oil yield zone, dolomite acid reaction slower than for lower yield zones, smokes and discolours easily; 68.0 m - criss-cross breccia of thin calcite veinlets in 0.3 m medium brown dolomite zone, equals density log peak, low kerogen content; 70.4 m, 71.0 m, 71.6 m - interbedded 10.1-15.2 cm dolomite zones; 74.7-75.0 m - 0.3 m dolomite zone with calcite in fractures; 78.6 m and 61.0 m - thin dolomite beds; 82.6-83.2 m - mostly dolomite, drag folded and faulted

85.6-89.9 m (281-295'); transition zone of above to zone below - alternating 15.2 to 30.4 cm zones of above low grade shale (rubbled) to shale below - rubbly laminated shale decreases downward through the transition zone; in broken hard zones in rubbly shale above are massive dolomite marlstone; generally a low grade zone; 89.3 m and 89.9 m - calcite along bedding planes; 88.4 - 89.9 m - core missing

89.9-105.2 m (295-345'); marlstone, dolomitic, medium to dark brown; very finely laminated, varved, but does not break easily on varves; "blocky", darkest laminae appear to be entirely organic; acid reaction very slow after considerable heating; can be ignited; scattered thin calcite veins parallel to bedding; "blocky laminated marlstone"; 103.6-105.2 m - rubbled faulted shear zone caved so lower density log relates to hole size

105.2-114.3 m (345-375'); marlstone, dolomitic medium to dark brown; hard; massive; only very fine indistinct bedding but varving still evident; will break on bedding planes but not as easily as the blocky type above; occasional calcite veining; 110.6-112.8 m - non-oil shale, dense zone, weathers to a light brown; reacts to acid only after considerable time and heat

114.3-186.8 m (375-613'); marlstone, dolomitic, dark grey-brown; blocky; very finely laminated fissile shale; very finely varved; splits easily; same as zone 89.9-105.2 m; reacts slowly to acid after considerable time; smokes and glows easily and will ignite: occasional calcite along wavy contorted laminae; although fissile the zone does not rubble easily; breaks into discrete "plates"; below 125.0 m becomes generally harder; retains most of varved laminations but splits less easily than above; has occasional zones becoming more massive as at 133.5-134.1, 135.6-136.2, 138.4-143.9 m; zone 138.4-143.9 m has indistinct laminae throughout and is transitional to blocky and massive types; note: this is somewhat "poorer" zone on density logs and assays; 126.5-127.4 m has several 0.6 cm thin beds of apparent ash (?); very soft; oxidized weathering zone, composed of clear indistinct crystals and apparent organic debris; albertite and/or oil shale; clear material is soft and breaks easily, does not scratch, could be thin zone containing silts as in the Green River; from 126.5 m down, the total zone exhibits microfaults and a slight waviness to the bedding in the higher angle zones; considerable contorting at the top of the fault layers; 178.0-180.0 m - thin seams and patches of clear crystals and black material, oxidized vugs center on these patches; several zones of good micro-ptygmatic folds; 186.2 m - 0.3 m grey medium to coarse grained tight sandstone

186.8-187.1 m (613-614'); sandstone, light to medium grey; medium to coarse grained; tight

187.1-233.5 m (614-766'); core missing

233.5-256.3 m (766-841'); marlstone, medium grey to dark brown-grey, slightly dolomitic; grey less dolomitic than brown ; mostly very finely laminated; fissile; probably high clay content; generally rubbles easily; becoming harder and much less rubbly as beds hold together at base of zone where yields improve; these zones are browner and become more dolomitic; fissile, but do not easily provide a thin edge for attempted lighting; petroleum odor on heating, smokes somewhat but do not light; the best zone at the base flakes to thin laminae but does not hold together well; papery rather than blocky; best zone smokes and glows, shows dolomite micro-crystallinity, reacts slowly to acid when heated

256.3 m (841'); T.D.

Canadian Occidental Petroleum Albert Mines 4

vertical
elevation: 103.6 m

12.2-29.0 m (40-95'); shale, colour varies from light to dark grey; calcite fracture filling; fine to medium grained calcareous sandstone injections both parallel to and cross cutting bedding, in places cut by calcite fracture fillings; darker colouration below 21.3 m; bedding exhibits tight syngenetic folding; slickensides on bedding planes are common; minor quantity of sulphur bloom at 20.7 m; core rubblizes upon movement

29.0-125.6 m (95-412'); dolomitic claystone, dark grey; weathered surface exhibits alternating light grey and tan colouration (<2.5 cm); slickensides on calcite veins; calcareous sandstone (1.3 cm) cross-cuts bedding at 53.9 m; slickensides on carbonaceous trash at 91.4 m; 96.3-100.9 m - core missing; 93.9-110.9 m - difficult to determine depths; 121.9-125.0 m - difficult to determine depths

125.6-129.5 m (412-425'); argillaceous limestone; banded; medium grey; varved

129.5-140.2 m (425-460'); shale, medium grey; portions tend to a claystone but generally core retains competency with development of shaly cleavage; folding with boudinaged sandstone bed (2.5 cm) at 138.1-138.7 m

140.2-147.2 m (460-483'); argillite, dark grey; decrease in obvious bedding

147.2-160.9 m (483-528'); core missing

160.9-196.6 m (528-645'); dolomitic shale, medium to dary grey; calcite veins (1.3 cm) parallel to and cross-cutting bedding; portions of the core tend to lose fissility and tend to blocky fracture; 169.5 m - (vicinity of) difficult to determine depths; numerous fine-grained sandstone beds in the vicinity of 180.7 m with notable increased sand content at 185.3 m with surface alteration of feldspars noted; bed overturn at 196.0 m

196.6-237.1 m (645-778'); dolostone; as above with no fissility

237.1-237.7 m (778-780'); limestone; massive; light grey to brown

237.7-250.9 m (780-823'); dolostone to dolomitic shale, medium to dark grey

250.9-253.3 m (823-831'); sandstone, fine to medium grained, light tan to medium brown; structureless; carbonaceous trash

253.3-256.0 m (831-840'); dolomitic siltstone, medium brown; carbonaceous trash

256.0-293.5 m (840-963'); dolostone, medium brown; distinct bedding; core is more competent than any previous; carbonaceous trash; minor non-calcareous siltstone; numerous syngenetic bed contortions

293.5-295.0 m (963-968'); siltstone and fine-grained sandstone; minor cross-beds and mica noted at 294.7 m

295.0-310.9 m (968-1020'); dolostone, dark-medium grey/brown; increased bedding; competent core to 304.8 m after which rubblization increases; sandstone beds below 308.8 m, 2.5 to 3.0 cm thick

310.9-316.4 m (1020-1038'); shale, dark-grey; tight recumbent fold at 315.2 m; rubblized core

316.4-361.2 m (1038-1185'); dolostone and shale, medium to dark grey; fine-bedding; below 343.8 m increased sandstone beds (2.5-3.0 cm); increased bedding density below 349.9 m combined with increased fissility and rubblization; core totally rubblized below 353.0 m; darkening of colour towards 361.2 m

361.2-361.8 m (1185-1187'); conglomerate, dark grey; quartz pebble content; poorly sorted

361.8-400.0 m (1187-1312'); shale and claystone, dark grey, in part black; usually rubblized; thin (5.0-7.6 cm) beds of light grey and brown medium to coarse grained sandstone and polymictic conglomerate, some showing graded bedding; low oil content, 376.4-377.3 m, "snaps" on heating giving an oily odour; carbon trash at 394.7 m

400.0-408.7 m (1312-1341'); shale, dark to medium grey; lightening of colour and increased fissility; thin sandstone beds remain; well-developed microlaminae; scattered low quality oil bearing shale; rubblization decreases to nonexistent at 402.3 m

408.7-409.0 m (1341-1342'); dolomitic marlstone, dark brown; competent core; indistinct, discontinuous laminae

409.0-410.6 m (1342-1347'); shale, medium grey; well-developed microlaminae; numerous calcite bands parallel to bedding

410.6-411.5 m (1347-1350'); as 408.7-409.0 m

411.5-417.0 m (1350-1368'); shale, light to medium grey; grades into dolomitic marlstone, 80% of which exhibits fissility, 20% with no fissility; sandstone bed (0.3 m) at 416.0 m

417.0-420.0 m (1368-1378'); dolomitic marlstone, dark brown; competent core; indistinct, discontinuous laminae; minor calcite veining

420.0-426.1 m (1378-1398'); shale, medium grey; rubblized, although portions retain competency indicating some oil content; sandstone bed (5.0 cm) at 423.1 m

426.1-434.9 m (1398-1427'); footage confusion in Box 101; dolomitic marlstone, dark brown; well-developed microlaminae; competent core; calcareous sandstone interbeds; overturned bedding at 427.0, 434.0 and 434.3 m; sandstone beds at 434.9 m (2.5 cm), oil bearing

434.9-442.9 m (1427-1453'); dolomitic marlstone, dark brown; competent core, rubblized between 439.8-442.0 m; discontinuous microlaminae, although distinguishable not well developed; contorted bedding at 435.6-435.9 m; sandstone bed at 438.3 m (0.5 m), oil bearing

442.9-444.4 m (1453-1458'); dolomitic marlstone, dark brown; competent core; well developed microlaminae

444.4-445.3 m (1458-1461'); sandstone, calcareous; dense; medium grained

445.3-482.5 m (1461-1583'); dolomitic marlstone, dark brown; generally competent core, however, contorted bedding at 455.1 m progresses into rubblized core and vertical dips between 456.3-457.2 m; portions are fissile; well developed microlaminae; sandstone beds (2.5-5.0 cm), oil bearing; very contorted bedding at 449.0 m; scattered sulphur rich zones, notable by "pods" of obvious sulphur bloom, which vary from 3.0-7.6 m in thickness; 462.7-463.3 m - calcite fracture filling and laminae terminating in sandstone; brecciated marlstone at 464.5-464.8 and 470.9-471.5 m; calcareous sandstone at 469.7-470.0 m

482.5-484.0 m (1583-1588'); dolomitic marlstone, dark brown; competent core; well developed microlaminae, although contorted; sandstone beds

484.0-485.5 m (1588-1593'); dolomitic marlstone, dark brown; competent core; indistinct, discontinuous microlaminae; portions tend to increased sand content

485.5-495.6 m (1593-1626'); dolomitic marlstone, dark brown; competent core; varying degrees of continuity and distinctness of microlaminae which are highly contorted; sulphur bloom between 491.9-493.8 m

495.6-497.7 m (1626-1633'); claystone and shale, dark grey; some minor oil content

497.7-498.7 m (1633-1636'); dolomitic marlstone, dark brown; competent core; distinct, continuous microlaminae; contorted bedding (microlaminae)

498.7-499.3 m (1636-1638'); sandstone, calcareous, medium-grained; in part conglomeratic

499.3-502.9 m (1638-1650'); dolomitic marlstone, dark brown; competent core to approximately 502.9 m where rubblized shale becomes prominent; distinct, continuous microlaminae

502.9-505.4 m (1650-1658'); sandstone, medium-grained to quartz conglomerate; siliceous; dense

505.4-520.6 m (1658-1708'); shale, dark to medium grey and brown; rubblized core

520.6 m (1708'); T.D.

Canadian Occidental Petroleum Albert Mines 5

vertical
elevation: 114.3 m

13.7-39.6 m (45-130'); claystone, medium grey; portions exhibiting reasonable fissility; well developed microlaminae; carbonaceous plant fragments at 39.6 m; darkening of colour below 30.5 m; portions of the core are completely rubblized with 25-80% missing, as a result depths are approximate

39.6-47.2 m (130-155'); dolomitic marlstone, dark grey; well developed microlaminae; increased blocky nature to the core; difficult to estimate depths

47.2-49.1 m (155-161'); dolomitic marlstone, dark brown; portions of both poorly and well developed microlaminae; core maintains competency

49.1-67.1 m (161-220'); dolomitic marlstone, dark brown-grey; microlaminated; some organic content, although low; rubblized core, the bulk of which is missing; tan coloured (weathered) lenses within a light grey (weathered) shale which exhibits contorted bedding; albertite veins at 59.7, 60.4 and 61.6 m cutting core at 75° and 40° to bedding, albertite vein is very regular compared to the bedding

67.1-79.2 m (220-260'); as above; increased organic content as indicated by the brown colouration and competency of the core

79.2-137.2 m (260-450'); shale, medium grey; core preservation is very poor with the bulk missing

137.2-153.6 m (450-504') dolomitic marlstone, dark brown; well developed microlaminae; little fissility; core preservation is very poor with the bulk missing; it is suspected that the readily weathered low organic content shale indicated on the lithologic log has disappeared.

153.6-156.7 m (504-514'); as above; approximately 30% of the core exhibits fissility; numerous calcareous sandstone beds (2.5 cm thick)

156.7-158.5 m (514-520'); claystone, medium grey; rubblized to angular "chunks"

158.5-185.9 m (520-610'); dolomitic marlstone, dark brown; portions exhibit well developed microlaminae; 158.2-162.8 m - confused depth markers with 60% of the core missing

185.9-190.8 m (610-626'); dolomitic marlstone; exhibits fissility; bulk of core missing, depths unknown or just guesses

190.8-195.1 m (626-640'); dolomitic marlstone, medium grey to brown; well developed microlaminae both with and without fissility; rubblized core; organic content is likely low as indicated by the state of the preservation of the core

195.1-210.3 m (640-690'); dolomitic marlstone, dark brown; well developed microlaminae in a competent core; prominent (0.3-0.6 cm) calcite beds

210.3-211.8 m (690-695'); dolomitic marlstone, dark brown; discontinuous microlaminae; core partly missing, remainder mixed

211.8-212.4 m (695-697'); shale, medium grey; rubblized core; depths are guesses

212.4-217.0 m (697-712'); as 210.3-211.8 m

217.0-221.6 m (712-727'); core missing

221.6-243.2 m (727-798'); dolomitic marlstone, dark brown; competent core; distinct, well developed microlaminae at a regular angle; minor bedding contortion at 229.5 m; minor amount of fissility at 235.0 m; 231.0-232.6 m - missing

243.2-243.5 m (798-799'); dolomitic marlstone, dark brown to black; fissile; slickensides on bedding planes

243.5-281.3 m (799-923'); dolomitic marlstone, dark brown; competent core except the minor portions which exhibit fissility; well developed microlaminae except a portion between 247.5 and 251.5 m which exhibits poorly developed indistinct microlaminae, below 253.0 m, microlaminae regular, well developed; section between 247.5 and 251.5 m apparently of low oil content based on estimated specific gravity; in vicinity of 273.7 m, sulphur bloom is associated with carbonaceous trash and a white crystalline mineral; sandstone beds below 273.7 m as the 15 cm bed at 279.8 m

281.3-338.3 m (923-1110'); dolomitic marlstone, dark brown; indistinct microlaminae; the core is in very poor condition, very mixed and in part missing; rubblized shales and claystone fragments are present

338.3-342.0 m (1110-1122'); shale, light brown; rubblized core; small "plug" of core at 342 m (?) consists of crushed contorted shale shot with calcite stringers; rock appears to be associated with faulting and includes albertite fragments indicating post albertite movement

342.0-349.0 m (1122-1145'); dolomitic marlstone, dark brown; competent core; well developed microlaminae

349.0-355.1 m (1145-1165'); limestone; rubblized core; 5.0 to

7.6 cm sandstone beds; rubblized shale; some oil bearing microlaminated dark brown dolomitic marlstone

355.1-390.4 m (1165-1281'); dolomitic marlstone, dark brown; competent core except due to faulting; well developed microlaminae, contorted at 363.6 to 364.5 m; albertite vein at 364.8 m; 370.9 to 375.8 m, indicated by rubblized shale; the brecciation noted is likely due to lower kerogen content not promoting "slip"; portions exhibit indistinct microlaminae; 390.1 m - a zone of bedding contortion and disruption

390.4-411.5 m (1281-1350'); dolomitic marlstone, dark-medium brown; competent core; indistinct microlaminae tending to more continuous, distinct laminae in places

411.5-420.6 m (1350-1380'); as above; increased definition of microlaminae; crenulated bedding in places; sulphur bloom noted

420.6-480.0 m (1380-1575'); as above; albertite veins at 435.3, 436.5 and 463.5 m; 450.8-456.6 m missing

480.0-697.7 m (1575-2289'); as above; decreased continuity of microlaminae; 541.9 m - brecciated; 678.5-679.4 m - brecciated; 693.4-694.0 m - brecciated

697.7-701.0 m (2289-2300'); as above; increased sandstone content although not continuous; prominent quartz grains up to 0.5 cm, many angular

701.0-773.0 m (2300-2536'); as above, decreased sandstone content to "normal" dolomitic marlstone exhibiting indistinct microlaminae in competent core; portions exhibit well defined microlaminae; towards bottom of the section hardness increases indicating increased quartz content relative to kerogen; reduction of core size at 717.5 m but maintaining core box size increases core movement within the box resulting in increased depth error below 717.5 m; 768.1-771.1 m - missing

773.0-792.5 m (2536-2600'); as above with regards to lithotype, however, kerogen content drops, therefore colour lightens to grey (no brown); portions are oil bearing but were not assayed; core is rubblized, a function of kerogen content; increased rubblization below 789.4 m; 788.2 m - sand beds, 15.2 cm thick

792.5-870.8 m (2600-2622'); dolomitic marlstones and shales; 798.3-799.2 m - crushed, crenulated zone above shales exhibiting vertical bedding; shales contain some kerogen although minimal given their burning characteristics, some "popping", smoking, no flame; brecciated at 816.6-817.2,

836.1-836.7, 838.2-839.1 and 847.1-847.6 m

870.8 m (2857'); T.D.

Canadian Occidental Petroleum Albert Mines 6

vertical
elevation: 120.4 m

10.4-39.0 m (34-128'); shale, medium brown; in part tends to claystone (where lacking fissility); slightly oil bearing, given burning characteristics; 11.6-11.9 m - quartzose sandstone; 36.0 m - siltstone (15.2 cm); low oil content zones rubblize, higher content zones are more competent; bedding not very evident in bulk of the core; sandstone (2.5-5.0 cm) beds noted; carbonaceous plant fragments, random distribution; random scatter of black weathered material surrounded by sulphur bloom, possibly plant fragments; 26.5-31.4 m - missing

39.0-51.8 m (128-170'); shale, medium grey; rubblized; siltstone beds, 0.3 m at 42.6 and 51.2 m and 15 cm at 46.6 and 49.4 m

51.8-75.0 m (170-246'); shale to claystone; nonrubblized portion; core splits into discrete "plates"; surface weathers to distinct bands of dark grey and tan; portions are completely rubblized; no apparent structural complexities, bedding is regular; 15.2 cm brecciated zone at 69.8 m

75.0-77.1 m (246-253'); dolomitic marlstone, dark brown; competent core; bedding of varying distinctiveness although the bulk of the section exhibits little well defined continuous laminae

77.1-87.5 m (253-287'); shale, dark grey to brown; rubblization to nearly total disintegration of the core, although portions are more competent

87.5-102.4 m (287-336'); dolomitic marlstone, dark grey to brown; core maintains competency; laminae increases in distinctiveness and continuity to the point at 91.4 m where fissility occurs in places but decreases again by 93.9 m; slickensides at 93.9 and 97.5 m; some laminae contortion at 93.0 m; rubblized shale at 87.8 and 89.6 m

102.4-103.6 m (336-340'); shale; rubblized; slickensides

103.6-104.5 m (340-343'); dolomitic marlstone, dark brown; competent core exhibiting continuous, distinctive microlaminae

104.5-105.5 m (343-346'); as above, exhibiting fissility

105.5-108.8 m (346-357'); shale; rubblized; portions slickensided

108.8-117.3 m (357-385'); dolomitic marlstone, dark brown; competent core; well developed microlaminae tending to a shale (fissility) at 114.6 m; 114.6-116.1 m - a zone of

rubblized core which appears to be a zone of movement; high angle bedding at 114.9 m is followed by fragments of tight fold remnants; a similar zone also exists between 121.9 and 122.5 m

117.3-126.5 m (385-415'); dolomitic marlstone, dark brown; competent core; indistinct microlaminae; oil content likely not high given its high specific gravity; minor rubblized sections exhibiting slickensides

126.5-137.8 m (415-452'); dolomitic marlstone, dark brown; competent core; laminae development varies

137.8-141.7 m (452-465'); dolomitic marlstone, dark brown; indistinct microlaminae; core competency is rather poor in that the core is shattered; at 140.5 m a 15 cm section of rubblized material indicating movement

141.7-147.8 m (465-485'); dolomitic marlstone, dark brown; distinct laminae; competent core

147.8-149.3 m (485-490'); dolomitic marlstone, dark brown; indistinct laminae; competent core

149.3-151.5 m (490-497'); dolomitic marlstone, dark brown distinct laminae; competent core

151.5-154.2 m (497-506'); dolomitic marlstone, dark brown; development of laminae begins as rather indistinct but improves by 154.2 m; competent core

154.2-161.2 m (506-529'); dolomitic marlstone, dark brown; distinct laminae; competent core

161.2-182.9 m (529-600'); dolomitic marlstone, dark brown; 164.0-165.2 m - is hard and massive, although bedding is visible it tends to be thicker than any previously noted, organic rich beds are rather thick with thin laminae of dolomite interbedded, the typical varved appearance is lacking; section retains its brown colouration as opposed to the usual outer grey colour (weathered); below 178.6 m grey/brown weathered mottling increases to the scale of individual beds which imparts a distinctive mottling

182.9-190.5 m (600-625'); dolomitic marlstone, dark brown; competent core; increase in distinctiveness of laminae and their regularity compared to that section above but not the point exhibited by the distinctively varved sections; brecciated portions although core retains competency; weathered colouration is again grey

190.5-196.6 m (625-645'); as above with decrease in distinctiveness of the laminae

196.6-200.9 m (645-659'); as above with increase in distinctiveness of the laminae although portions exhibit less distinctive laminae

200.9-202.7 m (659-665'); as above with decrease in distinctiveness of the laminae

202.7-204.8 m (665-672'); as above with increase in distinctiveness of the laminae

204.8-232.6 m (672-763'); as above with decrease in distinctiveness of the laminae; brown colouration on weathered surface

232.6-245.4 m (763-805'); as above with laminations varying in distinctiveness and continuity; grey colouration on weathered surface; 238.7-239.9 m - missing

245.4-253.0 m (805-830'); as above with decrease in distinctiveness of the laminae; extremely hard sandstone unit at 249.0-249.6 m; slickensides at 253.0 m

253.0-256.9 m (830-843'); as above with increase, to some degree, in distinctiveness of the laminae; laminae are not as distinctive nor as regular as has been noted; sandstone unit at 255.1-255.7 m

256.9-298.1 m (843-978'); as above; high yield section between 281.9-285.0 m shows no obvious variations from the rest of the section

298.1-299.6 m (978-983'); as above with rather well developed laminations

299.6-299.9 m (983-984'); sandstone, dark brown; fine to medium grained

299.9-311.2 m (984-1021'); dolomitic marlstone, dark brown; competent core; laminations of varying distinctiveness

311.2-313.9 m (1021-1030'); as above with well developed, distinct laminae

313.9-315.5 m (1030-1035'); as above with decrease in distinctiveness of the laminae

315.5-316.7 m (1035-1039'); as above with increase in distinctiveness of the laminae

316.7-319.7 m (1039-1049'); as above with decrease in distinctiveness of the laminae; 0.6 to 1.9 cm brecciated zone cross cutting laminae (318.5 m) at 90°

319.7-326.4 m (1049-1071'); as above, with increased distinctiveness of the laminae

326.4-331.3 m (1071-1087'); as above with a general decrease in distinctiveness of the laminae although their degree of distinctiveness varies

331.3-335.3 m (1087-1100'); as above with increased distinctiveness of the laminae; albertite vein at 333.8 m; 15.2 cm sandstone at 334.4 m

335.3-349.3 m (1100-1146'); as above with distinct laminae which are discontinuous; sandstone (2.5 cm) at 336.2 m; albertite vein at 342.9 m; 343.5-345.6 - exhibits laminae, notable is a "flow" breccia appearance (also noted at 346.6-349.3 m)

349.3-353.3 m (1146-1159'); as above with increased core degeneration towards 352.0 m; folding and slickensides at 352.3 m

353.3-373.4 m (1159-1225'); claystone, medium grey; beds of siltstone (5.0-10.0 cm); rubblized core; 1.0 m zone of slickensided shales and siltstones at either 368.8 or 366.7 m (depth indicators missing)

373.4-378.9 m (1225-1243'); shale, light-medium grey; numerous calcareous beds (1 mm to 2 cm)

378.9-462.1 m (1243-1516'); claystone (40%), siltstone (40%), shale (20%), light to medium grey; beds of varying thickness; portions of microlaminated shale containing minor oil content

462.1-479.5 m (1516'-TD); dolomitic marlstone, dark grey; varved; fissile; some oil content although minor; no burning only "snapping" when flame is applied; core maintains its form, has not degenerated

479.5 m (1573'); T.D.

Canadian Occidental Petroleum Albert Mines 7

vertical
elevation: 129.5 m

10.7-21.3 m (35-70'); conglomerate, polymictic pebble, grey-brown matrix; igneous (including quartz), metasediment and metavolcanic pebbles; interbedded bands of microlaminated sandstones and siltstones tending to claystone in places; finer grained fractions are well sorted as opposed to the conglomerate itself; weathered conglomerate shows brown/tan matrix; increased lamination of claystone and siltstone below 13.7 m; some very small calcareous fragments; oil bearing

21.3-31.1 m (70-102'); shale, light grey; microlaminated; calcareous laminae and fracture filling; depth indicators in very poor condition

31.1-58.5 m (102-192'); sandstone and siltstone, dark grey; regularly laminated beds up to 1.3 cm thick; at approximately 38.4-39.0 m pebbles included; coarse fraction beds to a maximum of 15 to 30 cm; calcite beds (1 mm) produce white/black banding in the fine grained fraction

58.5-59.1 m (192-194'); conglomerate, green; very hard; dense; in part calcareous

59.1-77.7 m (194-255'); claystone and siltstone, dark grey to brown; increase in proportion of fine grained fraction; microlaminated with beds (0.6-1.2 cm) of fine to medium grained sandstone; generally coarser than any lithology to this point; with increased proportion of regular, distinct laminae oil content become evident

77.7-85.3 m (255-280'); dolomitic marlstone, dark grey to brown; distinct laminae; competent; dense; sandy units present

85.3-94.5 m (280-310'); as above with decrease in distinctiveness of laminae

94.5-128.6 m (310-422'); as above; increase in thickness and number of sandstone beds to a predominantly sandstone bed at 96.3 m (3.8 cm) returning to alternative fine and coarse fraction beds below; a very coarse sandstone to conglomerate (5 cm) at 100.5 m; 105.2 m - medium grained oil bearing sandstone with minor laminated siltstone; 107.3 m - polymictic oil bearing pebble conglomerate; 107.9 m - fine-medium grained oil bearing sandstone; 108.5 m - polymictic oil bearing pebble conglomerate; 109.1 m - fine to coarse grained sandstone grading into microlaminated oil-bearing dolomitic marlstone grading back into medium grained sandstone; conglomerate pebbles exhibit moderate rounding; depth confusion below 111.3 m

although oil-bearing microlaminated dolomitic marlstone is present

128.6-132.6 m (422-435'); siltstone, laminated; contorted, folds present; very coarse sandstone in direct contact with siltstone; pebbles of laminated siltstone within a breccia; although laminated, core is distinctly not as orderly as above

132.6-152.4 m (435-500'); siltstone and sandstone; poor depth markers; interbedded siltstone and fine to coarse sandstone

152.4-153.9 m (500-505'); core rubbled

153.9-194.5 m (505-638'); sandstone, medium to coarse grained; oil-bearing, although drops off in the vicinity of 160.0 m; slightly calcareous sandstone; 158.5-158.8 m - zone of fracturing; scattered carbonaceous trash; 162.4 m - a 0.5 m zone of black rubblized, slickensided shale containing pebbles of tan coloured (weathered) siltstone; 160.9-163.1 m - predominantly sandstone and conglomerate with minor shale; below 163.1 m coarse sandstone and conglomerate increase

194.5-204.5 m (638-671'); polymictic conglomerate, green matrix, mottled brown; free oil, "tar-like", in fractures and what porosity is available

204.5-209.7 m (671-688'); sandstone, medium to coarse grained, dark brown; oil bearing; bedding evident but not as distinctive as in siltstone; laminations become more evident as percentage of fine sandstone and siltstone increases

209.7-220.7 m (688-724'); polymictic conglomerate, green matrix with mottled brown; notable quantity of "tar" along fractures in core in Box 51; brown mottling caused by oil content

220.7-240.8 m (724-790'); siltstone and sandstone, dark grey to brown; calcareous, medium to coarse grained sandstone of low (if any) oil content; bedding more evident in finer fractions; sandstone at 224.3-224.6 m has good graded bedding; at 231.0 m progressing into microlaminated dark brown dolomitic siltstone which grades into a medium to coarse sandstone by 232.9 m

240.8-247.5 m (790-812'); siltstone and sandstone, dark brown; appears similar to the organic bearing dolomitic marlstone but exhibits increased grain size; predominantly medium grained sandstone interbedded with siltstone producing fairly regular and continuous bedding; coarse sandstone and conglomerate disrupt ordered bedding as they tend to be thick (at least 0.3 m)

247.5-253.0 m (812-830'); siltstone and sandstone, dark brown; fine to medium grained sandstone; 0.3-1.0 m thick beds of very coarse sandstone to conglomerate

253.0-262.7 m (830-862'); polymictic conglomerate, mottled green and dark brown; oil bearing; very sharp contact between upper well banded sandstone and siltstone; some large pebbles (6-10 cm) which are obvious but do not predominate

262.7-271.0 m (862-889'); siltstone and sandstone, dark brown; massive oil bearing siltstone grades, over 1.0-1.3 m into laminated fine grained sandstone and siltstone which exhibit minor calcite beds; reversal of this section back into conglomerate

271.0-281.3 m (889-923'); siltstone and sandstone; laminated siltstone and fine to coarse grained sandstones interbedded to produce a regularly bedded unit; increased grain size to conglomerate beyond 277.4 m

281.3-283.5 m (923-930'); conglomerate; fairly well sorted pebble conglomerate with low oil content

283.5-336.8 m (930-1105'); siltstone and sandstone; laminated siltstone, medium to coarse sandstone with conglomerate; 289.3 m - 0.3 m conglomerate bed over 15 cm graded medium to coarse sandstone which grades into a poorly sorted pebble conglomerate; minimal oil content

336.8-371.9 m (1105-1220'); shale and sandstone; interbedded with some conglomerate; shales appear to be of low oil content; sands and conglomerate contain some oil; laminated siltstone although not microlaminated; portions dolomitic

371.9-390.0 m (1220-1278'); sandstone and conglomerate; predominantly medium to coarse sandstone with conglomerate and interbedded shale and siltstone; poorly sorted conglomerate, high, fine to medium grained sandstone matrix with average 1 cm pebbles randomly distributed; some large (up to 5 cm) pebbles noted; conglomerate (386.5-390.0 m) contains very large pebbles some to cobble size

390.0-396.2 m (1278-1300'); sandstone and siltstone, dark brown; fine interbedding of fine to coarse grained sandstone and siltstone; increased oil content relative to sections above

396.2-397.2 m (1300-1303'); conglomerate and sandstone; grades into the above section

397.2-409.7 m (1303-1344'); sandstone and siltstone; fine interbedding of medium to coarse grained sandstone and siltstone; conglomerate and coarse grained sandstone beds (2.5-10.0 cm); 403.6 m maybe a thrust zone; a fine siltstone and slickensided shale over a pebble conglomerate; oil content dropped;

grades into conglomerate at 406.6 m; general appearance is one of alternating beds of siltstone/sandstone/ conglomerate grading from coarse into fine

409.7-422.5 m (1344-1386'); as above with reduced percentage of conglomerate

422.5-438.3 m (1386-1438'); polymictic conglomerate; minor beds of fine to medium sandstone and siltstone; finer fracti ns appears to have a higher oil content

438.3-442.8 m (1438-1453'); dolomitic marlstone, brown; competent core; indistinct laminae; grades into coarse sections both above and below

442.8-457.2 m (1453-1500'); conglomerate and medium to coarse grained sandstone; poorly sorted conglomerate; zone of possible movement indicated by slickensides at 442.9 m; pebbles are randomly scattered in a siltstone and sandstone matrix

457.2-457.8 m (1500-1502'); fault zone

457.8-468.2 m (1502-1536'); as 442.8-457.2 m; fine grained units exhibit slickensides; some oil content in all size fractions

468.2-472.4 m (1536-1550'); fine to medium grained sandstone and siltstone grading into pebble to cobble conglomerate at 469.4-469.7 m with fine fraction below which grades into conglomerate at 470.9-471.5 m with coarse sandstone to 472.4 m

472.4-472.7 m (1550-1551'); fault zone; core degeneration and slickensides

472.7-478.8 m (1551-1571'); sandstone, poorly sorted coarse grained; varying degree of sorting; dolostone matrix material

478.8-524.3 m (1571-1720'); polymictic conglomerate, light brown to grey; reasonably well sorted; some oil content; large pebbles present; grades into predominantly medium sandstone at 487.7 m; thin interbeds of fine sandstone and siltstone; 513.0 m erosional contact of conglomerate on laminated siltstone

524.3-534.0 m (1720-1752'); polymictic conglomerate and siltstone; conglomerate exhibits black slickensides and very fractured core; colouration is due largely to the fine matrix which is darker than that up the hole; slickensides permeate all core, evident where core is brown in colour

534.0-537.1 m (1752-1762'); polymictic conglomerate, green; no oil content

537.1-539.5 m (1762-1770'); siltstone, very dark grey to brown; laminated; grades into conglomerate with same siltstone matrix

539.5-547.1 m (1770-1795'); siltstone and medium grained sandstone, very dark grey; in part conglomeratic; entire section is rubblized, abundant slickensides

547.1-551.7 m (1795-1810'); limestone, dark grey to black

551.7-556.3 m (1810-1825'); coarse grained sandstone and polymictic conglomerates; no oil content

556.3-558.1 m (1825-1831'); limestone, dark grey to black; grades into lower unit

558.1-585.2 m (1831-1920'); sandstone, medium grained; contorted, grades into conglomerate which shows some oil content at 561.1 m which appears to increase to 567.2 m at which point oil content drops off; interbedded dark grey siltstone

585.2-601.1 m (1920'-TD); distinctive green colouration suggesting pervasive chloritization; faulting, slickensides

601.1 m (1972'); T.D.

AtlanticRichfieId Boudreau 1

40° off vertical towards S45°E (true)
elevation: 30.5 m .

43.6-51.2 m (143-168'); claystone to shale, medium grey, silty; massive to some finely laminated but not fissile; occasional offset of laminae along minor vertical (to core) fracture planes with calcite infill; some possible faulting, given the dip variations but this is difficult to confirm as core is rubbled and some zones are missing

51.2-53.6 m (168-176'); sandstone, light to medium brown; oil stained; fine grained; quartzose; some calcareous cement but reaction slow because of oil stain; extremely micaceous; very poor porosity; massive to uniform faintly laminated; no cross-beds evident; 10° to 15° dip

53.6-59.4 m (176-195'); shale, medium grey; contains 2, possibly 3, fault zones; massive but with thin zones containing laminae of fine grey quartzose sandstone; tight; minor pyrite in 59.1-59.4 m rubble zone

59.4-61.0 m (195-200'); sandstone, light brown, fine grained quartzose, calcareous, micaceous; wavy discontinuous clay laminae at top grades down to laminated sandstone

61.0-63.4 m (200-208'); shale, medium grey; massive, scattered, irregular, sandstone patches; plant debris on slickensided surfaces, rubbled, high dips; fault zone

63.4-65.2 m (208-214'); sandstone, light greyish-brown, fine grained, quartzose; calcareous cement; micaceous; scattered light brown stain; no effective porosity

65.2-66.1 m (214-217'); shale, medium grey, fault brecciated in top 0.5 m

66.1-66.8 m (217-219'); siltstone, light brown; very fine grained; quartzose; tight

66.8-70.4 m (219-231'); shale, medium grey; massive to some very poorly laminated, but not fissile

70.4-70.7 m (231-232'); siltstone, to very fine grained sandstone; brownish; quartzose; coarser downward; laminated to cross-bedded at base

70.7-72.2 m (232-237'); shale, grey

72.2-73.2 m (237-240'); sandstone to siltstone; cross-bedded

73.2-74.7 m (240-245'); shale, grey; with two sandstone zones (15 cm)

74.7-76.2 m (245-250'); sandstone, dark brown; oil stained; medium at top decreasing downward to very fine grained with decreasing stain to light brown at base; massive; no obvious dips

76.2-87.5 m (250-287'); shale, grey; massive; only in part sufficiently laminated to show dips by cleavage planes

78.3-78.6 m (257-258'); siltstone, light greyish-brown, quartzose; folded to vertical relative to core

78.6-80.2 m (258-263'); shale, grey

80.2-81.1 m (263-266'); siltstone, very light brown; thin fine grained sandstone beds; grades down to shale

81.1-84.4 m (266-277'); shale, grey; silt and sand laminae; siliceous; siltstone-sandstone zone (82.0-82.3 m)

84.4-88.4 m (277-290'); sandstone, brown; oil stained; quartzose; feldspar; fine to course grained; some poor to fair porosity; uniform general bedding; no evident cross-beds

88.4-89.3 m (290-293'); shale, medium grey; coaly debris as plants carbonized along rubble partings

89.3-92.4 m (293-303'); sandstone and shale; interbedded and gradational

92.4-93.6 m (303-307'); sandstone, brown; oil stained; fine to medium grained; siliceous; some poor porosity

93.6-95.1 m (307-312'); shale, grey

95.1-98.5 m (312-323'); sandstone; oil stained, portions heavily; regular bedding; no cross-beds; plant material at 98.5 m

98.5-99.7 m (323-327'); shale; grading downward to siltstone

99.7-100.9 m (327-331'); siltstone, grey; with interbedded shale

100.9-102.1 m (331-335'); sandstone, light brown; lightly stained

102.1-103.6 m (335-340'); shale, light to medium grey

103.6-104.5 m (340-343'); siltstone; grading down to sandstone

104.5-106.4 m (343-349'); sandstone, light grey; fine grained; grading down to light stain

106.4-108.2 m (349-355'); sandstone; lightly stained; fine grained; grading down to heavier stained medium grained

108.2-108.8 m (355-357'); shale, grey; high angle dips, 35°; slickensides, poorly laminated; non-fissile

108.8-109.4 m (357-359'); sandstone, light grey; not stained

109.4-111.3 m (359-365'); shale, light grey; poorly laminated

111.3-114.3 m (365-375'); siltstone and shale; inter-bedded

114.3-118.9 m (375-390'); sandstone, light grey; sub-laminated; flat bedded to some cross-beds and some wavy laminae; 117.7-118.0 m - calcite vein at 70° to core

118.9-119.2 m (390-391'); shale, light grey; laminated and sub-fissile

119.2-120.1 m (391-394'); sandstone, fine grained; cross-beds at base and top

120.1-130.8 m (394-429'); shale, light grey; laminated; fissile; slickensided; in part with brownish tinge and slightly dolomitic (less than 5%); slickensides mostly brown; in part has slight odor on heating; possibly minor kerogen laminae

130.8-132.6 m (429-435'); siltstone and sandstone; interbedded; medium grey; micaceous; hard; only vaguely defined laminae with coarser massive zones

132.6-137.5 m (435-451'); shale, light grey; finely laminated; some slight brown tinge; a few sand laminae; up to 5% varved dolomitic zones; smokes on heating; minor kerogen content; 135.6-137.2 m - with laminations of wavy bedded micaceous brown tinged siltstone; bedding somewhat indistinct

137.5-139.0 m (451-456'); siltstone, dark brown; coarse, micaceous; argillaceous; massive but may split in occasional clay laminae

139.0-139.9 m (456-459'); shale and siltstone; interbedded

139.9-141.1 m (459-463'); sandstone, medium to dark brown; finely laminated (flat); micaceous; argillaceous; siliceous; oil stain

141.1-142.3 m (463-467'); shale, medium grey; rubbled at top (fault zone ?); decreasing rubble downward to 40° dips overlying sandstone; interbeds with and grades down to sandstone

142.3-143.3 m (467-470'); sandstone, brown; laminated; oil stained; slightly calcareous; 40° dip overlies shale with 20° dip

143.3-144.2 m (470-473'); shale, grey-brown; laminated and slickensided at top becoming massive downward; some depositional slump

144.2-144.5 m (473-474'); sandstone; grades up and down to shale

144.5-147.2 m (474-483'); shale, grey; massive to very poor wavy indistinct lamination; non-dolomitic

147.2-148.1 m (483-486') sandstone, brown; oil stained; quartzose; some feldspar; minor calcareous cement; fair porosity; 1 m grey shale bed at base

148.1-148.7 m (486-488'); sandstone. light brown, as above, no stain, calcareous cement

148.7-151.2 m (488-496'); shale, grey; laminated; hard to some poorly fissile with brown slickensided planes; in part very finely varved; calcareous; possible minor kerogen content; no smoke on heating but possible faint odor; grades to massive non-calcareous zones; only irregular intervals with distinct calcareous-organic content

151.2-156.1 m (486-512'); siltstone and shale; interbedded massive grey shale and brown hard slightly calcareous sandy siltstone zones of each type to 0.3 m thick; constant bedding

156.1-159.1 m (512-522'); sandstone, light brown; slightly calcareous; some oil stained; generally poorly defined bedding; some indistinct wavy laminae and possible depositional slump zones; wavy discontinuous clay laminae in basal 1 m; very micaceous; trace cross-beds near base; traces slight micro-fracture offset of laminae

159.1-161.5 m (522-530'); shale-siltstone zone; massive shale; plant fragments at 159.4 m; basal 0.3 m badly brecciated, overturned and slickensided; pyrite

161.5-164.0 m (530-538'); sandstone, light to medium brown, indistinct bedded to massive

164.0-165.5 m (538-543'); shale, grey; slickensided; rubbled; fault zone (?)

165.5-166.1 m (543-545'); shale, grey; very finely laminated but not fissile; non-organic; no dip across core

166.1-167.3 m (545-549'); sandstone, light brown, micaceous, siliceous; slump

167.3-168.6 m (549-553'); siltstone, medium brown-grey; hard; siliceous; argillaceous

168.6-169.8 m (553-557'); shale, medium grey; sub-laminated

169.8-170.4 m (557-559'); sandstone, brown; oil stained

170.4-172.8 m (559-567'); sandstone, brown, fine grained; hard; in part calcareous; wavy flat irregular laminae evident from abundant plant debris

172.8-176.2 m (567-578'); shale, light to medium grey; sub-laminated; occasional fine flecks of carbonaceous debris; abundant interbedded finely laminated to very finely cross-bedded siltstone; grading to some light brown hard sandstone laminae

176.2-176.5 m (578-579'); shale, grey; rubbled; fault zone (?)

176.5-178.3 m (579-585'); sandstone and shale; interbedded to inter-laminated; very fine wavy laminae increasing downward in dip from 20° (relative to core) at 177.4 m to 50° at 178.0 m

178.3-189.3 m (585-621'); sandstone-shale; as above; shale zones rubbled from tectonic movement; high dips at top; rubble decreases downward; sandstone decreases downward; rubble slickensided; occasional thin interbeds of dolomite marlstone; some organic content (plant ?) in sandy zones

189.3-189.9 m (621-623'); shale; grading to marlstone; variably interbedded grey shale and brown marlstone; low grade; visible very fine discontinuous kerogen laminae

189.9-305.7 m (623-1003'); marlstone, light brown; in part argillaceous; mostly discontinuous kerogen flakes give faint but distinct wavy laminae; some definite carbonaceous (plant) debris; generally very low kerogen content; zones grade to greyish-brown poorly laminated dolomitic shale; shale mostly in top 15 m then all marlstone; occasional scattered very fine discontinuous quartzose sandstone lenses to laminae; generally silty; 199.6-201.8 m - greyish-brown shale, slightly dolomitic; 203.0-203.9 m - greyish-brown shale; 218.2-218.8 m - light brown marlstone; finely laminated, structurally contorted; 226.8 m - contorted, slickensided; 243.8-244.1 m - contorted with micro drag folds, 20-25° dip, on average 10° dip zone (relative to core), increasing kerogen laminae; 254.8-263.7 m - increased kerogen laminae, minor contortions (257.6 m), excellent laminae (259.1-262.1 m) decrease downward to minimal laminae in basal 1.5 m of zone, silty; 268.8-276.1 m - minimal kerogen laminae, essentially massive dolomite; 276.1-278.0 m - increasing laminae, some contortions and brecciation; 278.0-278.3 m - minimum discontinuous laminae only; 278.3-278.9 m - good laminae; contortions; 278.9-282.2 m - alternating bonds with good laminae and massive zones with poor kerogen; good laminae decrease downward, not disturbed; 282.2-305.7 m - dolomitic, massive, virtually no kerogen to traces only, a few zones with additional

laminae, occasional blebs and irregular bands of calcite; some silt to sand laminae; some carbonaceous debris

305.7-326.7 m (1003-1072'); marlstone, brown, massive dolomite type; abundant varves much more than in brown dolomite zone above; enough laminae in places to approach papery but never develops fissility; better zones are structurally contorted with small folds and brecciation; averages a good quality massive dolomite type; hard to split a thin edge; smokes, smells, glows red but does not burn; the degree of lamination is directly proportional to the assay yields; silty; 321.6-323.1 m - dolomite; 323.1-326.1 m - very finely varved, no contortions, not fissile

326.7-338.3 m (1072-1110'); marlstone; massive dolomite; brown; very faint kerogen flecks to occasional laminated beds (scattered zones, 333.8-335.3 m); not contorted; laminations never as good as zone above; argillaceous

338.3-343.5 m (1110-1127'); marlstone, brown; increasing laminations; no contortions

343.5-344.4 m (1127-1130'); marlstone, brown to grey, argillaceous; poor evidence of kerogen except for a few laminated zones

344.4-346.3 m (1130-1136'); marlstone; better laminated than above but still only poor to fair lamination

346.3-349.6 m (1137-1147'); marlstone, brown to grey; very argillaceous; some shaley cleavage but not really fissile

349.6-352.3 m (1147-1156'); marlstone, brown; laminated to some very poorly laminated; not fissile

352.3-377.3 m (1136-1238'); marlstone, brown; massive at top without any laminae and laminae increasing downward to good development, almost becomes papery but has very poor fissility; sandy in greyer zones (371.9 m); very brown as all grey disappears; very finely laminated; sandy below 371.9 m laminae decrease; zone becomes greyer at 377.3 m; basal several metres sub-fissile due to high clay content

377.3-380.1 m (1238-1247'); marlstone, brown; laminated; good zone; sub-fissile but does not split easily; not quite to the papery quality; smokes readily but hard to get thin edge that will burn; sandy to silty

380.1-394.1 m (1247-1293'); marlstone to shale, medium greyish-brown dolomitic; sub-fissile with poor cleavage resulting from clay content; "shale" character at 382.8 m more dolomitic; shark scales and teeth; ostracods filled by calcite and pyrite; 386.2-386.5 m - a few slickensides; 391.1-392.3 m - more massive, increased dolomite content;

392.3-392.6 m - slickensided, rubbled, possible fault zone

394.1-396.2 m (1293-1300'); shale, grey; slickensided and rubbled; possible fault zone; no major dip, changes so any fault must be low angle thrust

396.2-399.3 m (1300-1310'); shale, grey; non-dolomitic; sub-fissile with some breakage across bedding; rubbly, some thin zones of argillaceous dolomite

399.3-399.9 m (1310-1312'); dolomite, greyish-brown, argillaceous

399.9-400.5 m (1312-1314'); shale, grey

400.5-401.1 m (1314-1318'); dolomite, argillaceous

401.1-401.4 m (1316-1317'); shale, grey

401.4-404.5 m (1317-1327'); dolomite, brownish-grey, argillaceous

404.5-409.3 m (1327-1343'); shale, grey, non-dolomitic; splintered to rubble

409.3-409.7 m (1343-1344'); dolomite, brown to grey-brown; very finely laminated; almost varved

409.7-410.6 m (1344-1347'); dolomite, light greyish-brown; silty to sandy; 30% quartz; argillaceous and with clay patches; massive; minor carbonaceous debris

410.6-415.1 m (1347-1362'); shale, grey; rubbled; slickensided; thin zones of light brown dolomite

415.1-416.7 m (1362-1367'); dolomite, light greyish-brown; sandy; 30% fine grained quartz; argillaceous; massive; faint bedding defined by carbonaceous debris

416.7-420.0 m (1367-1378'); shale, medium brownish-grey, dolomite (±5%), rubbled with glossy slickensides, probable fault zone, bedding destroyed and slickensides at all angles

420.0-426.4 m (1378-1399'); shale, brownish-grey, dolomitic; sub-laminated to very poorly fissile; bedding not all destroyed; generally not badly rubbled except as below; zones of light brownish-grey quartzose dolomitic sandstone grading upward to sandy argillaceous dolomite; 423.4, 424.0, 424.6, 425.2-426.7 m, all badly contorted, fault zone

426.4-435.6 m (1399-1429'); dolomitic, marlstone, brown; laminated-varved; massive; continuous kerogen laminae, some sandy zones; laminae proportional to assay values; silty; 429.8-430.4 m - conglomerate, quartz pebbles in dolomite marlstone matrix; 431.6-431.9 m - conglomerate, as above,

coarsest at base decreasing upward to sandy dolomite and then to clean laminated marlstone; soft sediment flow into the marlstone; 433.1-433.7 m - traces of native sulphur; 433.7-444.7 m - thin zones and beds (20.3 cm) of quartz conglomerate with dolomite marl matrix

435.6-438.9 m (1429-1440'); conglomerate, quartz pebble; dolomite marl matrix; sandy marlstone beds to 25.0 cm thick

438.9-444.7 m (1440-1459'); marlstone, dolomitic, brown; very finely laminated to varved but not fissile, silty to sandy

444.7-445.6 m (1459-1462'); sandstone, coarse grained; some conglomeratic, quartz pebbles; dolomite marl matrix, 15.0 cm of marlstone at 445.3 m

445.6-449.3 m (1462-1474'); shale, grey; slickensided; rubbled; some dolomite marl zones not rubbled but show wavy bedding contortions

449.3-465.4 m (1474-1527'); marlstone; laminated; varved; massive; sandy patches; layers and laminae; interbedded grey shale laminae and zones grading to dominant shale; sub-fissile in shale zones; 461.8, 462.4, 463.0, 463.6-464.2 m - sandstone to sandy conglomerate zones to 10.0 cm thick

465.4-467.0 m (1527-1532'); conglomerate, quartz pebbles; dolomite marl and argillaceous matrix; some zones of dolomite marlstone with poor to fair discontinuous kerogen laminae

467.0-467.9 m (1532-1535'); marlstone, brown, sandy; laminated; massive

467.9-468.2 m (1535-1536'); conglomerate

468.2-470.0 m (1536-1542'); marlstone; slightly laminated; poor organic zone; gradational down to dolomite as varving is reduced; sandy

470.0-472.4 m (1542-1550'); dolomite; very minor organic content; only scattered discontinuous kerogen laminae, not enough to define bedding; solution partings

472.4-476.1 m (1550-1562'); sandy dolomite grading down to better varved marlstone by 474.9 m; sandy, conglomerate zones at 475.5 and 476.1 m

476.1-485.2 m (1562-1592'); contorted varved marlstone; increasing laminae quality downward to 481.6 m and then decreasing to 485.2 m; scattered sandy lenses and laminae; silty

485.2-504.4 m (1592-1655'); sandy, dolomite marlstone; discontinuous to some good laminae; sand lenses; occasional conglomerates; no good oil shale zones; marl appears

argillaceous; conglomerate zones at 494.4, 495.9, 496.2, 496.8, 502.0 m

504.4-516.6 m (1655-1695'); conglomerate, quartz and other pebbles; silt and sand quartz matrix; zones of mostly dolomite cement; tight

516.6-517.9 m (1695-1699'); marlstone, massive dolomite; silty; hard; very poorly varved

517.9-519.1 m (1699-1703'); conglomerate; quartz and other pebbles; dolomitic; some marl lenses

519.1-525.5 m (1703-1724'); marlstone, dolomite; poor to some fair organic laminae; poor organic zone; some conglomerate zones; dolomite contains scattered quartz and sandy lenses; conglomerate at 524.0, 539.5 and 342.3 m, a few large scattered quartz pebbles in the marl

525.5-530.7 m (1724-1741'); marlstone; very poor laminae; sandy; silty with numerous sand lenses and laminae; conglomerate at 525.8-526.4 m

530.7-531.9 m (1741-1745'); sandstone to conglomerate; grey; quartz pebbles; dolomite

531.9-546.2 m (1745-1792'); conglomerate; variety of pebbles to some dominant quartz pebble zones; some dolomite matrix

546.2-552.0 m (1792-1811'); marlstone, brown; very poor to some fair varving; sandstone laminae and lenses common throughout; sandy marl zones

552.0-553.5 m (1811-1816'); marlstone and conglomerate; 50/50;

553.5-558.1 m (1816-1831'); conglomerate

558.1-567.5 m (1831-1862'); marlstone; sandy and conglomerate zones; conglomerate (565.4-565.7 m)

567.5-568.8 m (1862-1866'); conglomerate

568.8-572.7 m (1866-1879'); marlstone; fractured; poor quality; conglomerate zones

572.7-579.7 m (1879-1902'); conglomerate with marlstone zones

579.7 m (1902'); T.D.

AtlanticRichfield Dover 1A

30° off vertical towards N25°E (true)
elevation: 59.4 m

4.9-13.4 m (16-44'); conglomerate and sandstone; light grey to greenish-grey; quartz-chert-rock pebbles; calcareous

13.4-21.6 m (44-71'); shale, brownish-grey; massive at top becoming finely laminated, fissile at base; slightly dolomitic with dolomite along lamination planes; in part grading to varved clay-dolomite; average 5% dolomite content; harder zone with greater dolomite content and contorted bedding at 19.2-19.5 m

21.6-23.2 m (71-76'); marlstone and shale; alternating very finely laminated varve-like; fissile; brownish-grey shale and brown dolomite marl with abundant fine kerogen laminae in thin papery zones

23.2-24.4 m (76-80'); marlstone, medium brown; massive; silty with very fine quartz (10-15%); occasional thin finely varved zones

24.4-25.6 m (80-84'); shale, light grey to brownish-grey; only very slightly dolomitic at top becoming browner and more dolomitic downward; chunky at top to sub-laminated; sub-fissile at base; grades down to marlstone

25.6-27.7 m (84-94'); marlstone to dolomite, light brown; very slightly silty (2% quartz); massive; flecks of organic debris and scattered zones with kerogen laminae; some flecks of organic debris appears carbonaceous

27.7-30.2 m (91-99'); shale, medium greyish-brown to brown, dolomitic; sub-laminated; sub-fissile on clay laminae; in part appears varved but clay not kerogen gives darker varve

30.2-31.4 m (99-103'); siltstone, light grey, quartzose; dolomite cement; tight; massive; silt decreases downward and grades to marlstone

31.4-36.3 m (103-119'); marlstone, brown; massive but with variable kerogen lamination; most laminae continuous; some bedding contortions

36.3-43.0 m (114-141'); shale, brownish-grey to greyish-brown; chunky to sub-laminated; slightly dolomitic with thin beds to 10.0 cm at 37.8-38.7 m of light brown varved massive marlstone; some concentrated kerogen laminae

43.0-44.8 m (141-147'); core missing

44.8-48.5 m (147-159'); sandstone, light brown, fine grained, quartzose; in part argillaceous; dolomite cement; massive to faint laminations

48.5-61.0 m (159-200'); shale, brownish-grey; dolomitic (15%); generally chunky, non-laminated; a few thin zones with dolomite varving; zone at 54.6 m with calcite laminations; in part appears non-dolomitic; slickensidesat 52.1 m with deformed rubble; slickensided and rubbled (59.7-61.0 m)

61.0-61.9 m (200-203'); dolomite, light brown; massive; hard; kerogen flecks at best, grades down to marlstone

61.9-63.4 m (203-208'); marlstone, dolomitic, medium brown; laminated to varved, continuous kerogen layers; some abundant kerogen laminae but not fissile; best laminae toward base of zone

63.4-65.5 m (208-215'); shale, medium grey to brownish-grey; chunky; slightly dolomitic (5% maximum)

65.5-65.8 m (215-216'); marlstone, brown; fair kerogen laminae development; massive; laminated

65.8-68.0 m (216-223'); shale, medium brownish-grey; chunky to sub-laminated which is poorly fissile; very slightly dolomitic

68.0-69.5 m (223-228'); marlstone, brown; massive dolomite type; good continuous kerogen laminae

69.5-74.4 m (228-244'); shale, grey; chunky; occasional zone with dolomite laminae; very slightly dolomitic at best (2% maximum); badly rubbled and slickensided (69.5-70.1 m), lesser degree (72.5-73.5 m)

74.4-79.2 m (244-260'); sandstone, light grey to light brown (oil stain); fine grained quartzose; argillaceous; dolomite cement; some interbeds of light grey massive claystone; only faint uniform bedding defined by colour and silt laminae

79.2-83.5 m (260-274'); shale, light greyish-brown; browner tinge distinctly evident in contrast to shales in overlying section; very slightly dolomitic (less than 2%); chunky to some sub-fissile cleavage

83.5-88.1 m (274-284'); shale, medium brownish-grey; very slightly dolomitic; occasional dolomite-rich bands; chunky; scattered slickensides

88.1-89.9 m (289-295'); marlstone brown; massive; with occasional thin bands containing kerogen laminae; closer to dolomite than marlstone

89.9-91.1 m (295-299'); sandstone, brown; heavily oil stained; fine to medium grained quartz and some feldspar grains; some siliceous overgrowth; poor porosity; may be ineffective; faint bedding, uniform, defined by grain size variations

91.1-104.2 m (299-342'); dolomite to marlstone; light brown massive; dolomite gradational to and interzoned with marlstone; brown marlstone is poorly laminated to some very slightly varved; faint to some good kerogen laminae; some discontinuous kerogen; all variations relate to differing kerogen content; some pressure solution to form organic partings

104.2-105.8 m (342-347'); marlstone, dolomite, medium brown; numerous kerogen laminae; best of interval grading down from dolomite-marlstone above

105.8-123.7 m (347-406'); dolomite, light brown; massive; argillaceous; no evidence of kerogen laminae; faint colour bedding; scattered smooth breakage; variable, silty (quartz)

123.7-140.8 m (406-462'); marlstone to dolomite; laminated kerogen zones and massive dolomite; variable but most has some varving; laminations vary commiserately with assay results; never very good zone; purer dolomite intervals often silty with very fine quartz; a few scattered intervals become fissile where argillaceous laminae are present; rock here much greyer

140.8-143.9 m (462-472'); shale, medium greyish-brown; chunky; dolomitic, in part with dolomite varves; some slickensides and rubble

143.9-144.5 m (472-474'); marlstone, brown, laminated; fair kerogen zones; some contortion and vertical dip (to core) at base

144.5-147.5 m (474-484'); marlstone (as above); slickensided; rubbled; sheared; fault zone

147.5-154.2 m (484-506'); dolomite and shale, light brown; massive dolomite; without kerogen laminae; interbedded greyish-brown dolomitic shale; shale partly rubbled and slickensided; dips and deformation decrease downward

154.2-156.1 m (506-512'); dolomite-marlstone-shale, light brown to greyish-brown; massive grading to clay laminae

156.1-161.8 m (512-531'); shale, medium greyish-brown; dolomitic (5-10%); brown massive dolomite zones (to 10 cm thick) in upper 2.5 m becoming more slickensided and rubbled downward to complete rubble below 159.1 m, probably a fault zone

161.8-162.2 m (531-532'); dolomite, dark greyish-brown; massive; quartz silt (40%) probably argillaceous; rubbled and criss-crossed by fine calcite veinlets

162.2-166.1 m (532-545'); shale, grey; rubbled; slickensided; evidence of dolomite laminae in zone with dips parallel to core axis

166.1-167.0 m (545-548'); marlstone, dolomitic; poor varving; overturned zone relative to core axis

167.0-168.6 m (548-553'); shale, grey; rubbled; slickensides

168.6-170.1 m (553-538'); dolomite, brown, quartz silt (up to 40%); probably also argillaceous; laminated but massive without cleavage; interbedded grey sub-fissile slightly dolomitic shale

170.1-173.7 m (558-570'); shale, grey; chunky to sub-fissile; slightly dolomitic; zones of sandy to silty dolomite; some kerogen and/or clay laminae (appear brown and grey); uniform dip to core axis; occasional slickensides and only slightly rubbled

173.7-177.4 m (570-582'); shale, grey; rubbled; slickensided; occasional pieces of dolomite with kerogen

177.4-179.8 m (582-590'); marlstone and shale; interbedded; some badly fractured dolomite with calcite infill; in part somewhat rubbled

179.8-180.1 m (590-591'); shale, grey; rubbled

180.1-181.4 m (591-595'); marlstone, brown; good kerogen lamination to varved; in part fissile; approaches ignition; papery type; dip decreases from 20° at top to level at base

181.4-182.0 m (895-897'); shale, grey; slickensided along bedding laminae

182.0-183.2 m (597-601'); marlstone, brown; fairly well varved grading to massive dolomite at base which is brecciated and filled by calcite

183.2-185.3 m (601-608'); shale, grey; chunky; only occasional slickenside

185.3-197.5 m (608-648'); marlstone, brown; varved; massive; variably fair to good kerogen laminae and grading to some massive dolostone; with interbedded zones of grey chunky, slightly dolomitic shale

197.5-201.2 m (648-660'); shale, greyish-brown, dolomitic; chunky to some slightly laminated; traces of carbonaceous debris

201.2-207.3 m (660-680'); marlstone, light brown; laminated; varved with brown kerogen, variably close spaced to 0.5 cm apart; massive; no fissility; uniform; no contortions

207.3-207.6 m (680-681'); transitional from above down to below

207.6-216.4 m (681-710'); shale, light grey; chunky to some poorly laminated and slightly fissile; no good bedding; planar cleavage; brecciation and slickensides (215.2-216.1 m)

216.4-231.6 m (710-760'); shale, light greyish-brown, dolomitic; sub-laminated; scattered zones grading to argillaceous dolomite; scattered kerogen laminae; slickensided (223.7-224.6 m) more massive and harder from 224.6 to 229.2 m

231.6-235.0 m (760-771'); sandstone, brown, oil stained, medium to fine grained quartz and possible feldspar, possible dolomite cement but acid reaction poor because of oil stain, some conglomerate pebbles near base, very heavy oil residue in fracture planes

235.0-239.0 m (771-784'); marlstone, light brown; silty in upper few metres below the sandstone; minimal kerogen laminae at top, increasing downward to 239.0 m

239.0-241.4 m (784-792'); core missing, should be optimum zone as base of above given the core assay values

241.4-249.9 m (792-820'); marlstone; brown grading down to light greyish-brown; decreasing varves and kerogen laminae downward as clay content appears to increase; grades down to shale

249.9-254.2 m (820-834'); shale, light brownish-grey, dolomitic; in part laminated and fissile by clay laminae; no significant kerogen in dolomitic zones

254.2-257.3 m (834-844'); dolomite, light brown; quartz silt (40%), argillaceous; faint bedding by clay content; massive; hard; minor vugs at 256.9 m; becoming greyer with patchy clay streaks below 256.9 m

257.3-257.9 m (844-846'); dolomite, light brown; brecciated, fragments of fine dolomite and some mud; calcite infill patches; fragments angular; local rip-up breccia; minimal transport

257.9-275.2 m (846-903'); dolomite, brown; quartz silt (25%); argillaceous, with grey bands and laminae of higher argillaceous content; generally massive but with a very poor fissility along bedding planes (probably relating to clay content); very uniform appearance except for variable grey tinge with varying clay content

275.2-318.8 m (903-1046'); shale, grey; hard; dolomitic; silt lenses and laminae; interbeds of brown silty dolomite; occasional shark scales; traces of carbonaceous debris; can be easily called silty argillaceous dolomite or silty dolomitic shale; generally very hard and massive except for silt laminae; general character of bottom clastic zone is one of varying amounts of quartz, dolomite and clay; generally very massive; only minimal evidence of lamination, all essentially across core at 10° or less

318.8 m (1046'); T.D.

Canadian Occidental Petroleum Rosevale 1

vertical
elevation: 229 m

0.0-246.9 m (0-810'); conglomerate, Hillsborough Formation; very coarse grained angular rubble in a matrix of red clay siltstone and some sand; many of the pebbles are green but overall colour is reddish to reddish-brown but becoming more obviously green to the base as pebble colours become more green downward; dips generally 25° at top decreasing to 15° at base, measured by scattered sandstone beds and shale zones

246.9-252.4 m (810-828'); shale, medium olive-grown to yellow-brown; dusky; laminated; fissile, rubbly; occasional bands to 5 cm thick of greeen, red and grey shale; some 3 cm beds of fine to medium grained soft sandstone; greenish colour of shale increases downward and becomes transitional to underlying marlstone; this zone not particularly dolomitic and does not appear to contain any kerogen; density log deflection relates to caving

252.4-268.8 m (828-882'); shale, dark grey, laminated; fissile; rubbles easily; dolomitic; possibly up to 30% dolomite content; becoming less subbly below 256.0 m as dolomite increases downward from minimal at top to possible 30%; all core rubbled if disturbed, breaks on attempt to pick up core size piece; a couple of thin reddish-brown non-dolomitic finely laminated bands (less than 1 cm) in top 1 m; very similar to papery marlstone, even though yields are extremely low; marlstone applies from dolomite content; dolomite is all microcrystalline with crystal faces only evident at x50 magnification; 253.8 m and 256.6 m - 5 cm bands of dolomite, grey-brown, massive; 260.0 m - 15 cm sandstone lense, light grey, fine grained, dense, hard; 260.0-260.6 m - mottled brown massive dolomite zones; 260.9-261.2 m - sandstone, light grey to brown, quartzose, fine grained, hard, calcareous cement; 262.7-263.3 m and at 264.3 m - criss-cross vein network of calcite filling of very fine fractures; dolomite content decreases below 259.1 m as zone becomes shale rather than marlstone; very little kerogen; change evident in density

268.8-271.9 m (882-892'); dolomite marlstone; massive, very indistinct laminae; no fissility; argillaceous; minimal kerogen; gradational to zones above and below and with some internal intervals grading to papery marlstone

271.9-273.1 m (892-896'); papery dolomite marlstone

273.1-273.4 m (856-897'); sandstone, light grey; hard; fine grained; calcareous

273.4-286.5 m (897-940'); shale, dark grey; very slightly dolomitic; laminated; fissile; rubbly

286.5-291.1 m (940-955'); marlstone; as above but slightly more dolomitic; less rubbled but still papery; odour on heating but does not smoke

291.1-296.6 m (955-973'); papery shales, dark grey to grey-brown; minimal dolomite content

296.6-303.6 m (973-996'); marlstone; becoming browner, hard, more dolomitic, slightly more kerogen; basal 1.2 m has very fine irregular patches and the laminae zones of white crystalline calcite; pyrite mineral veinlets

303.6-310.9 m (996-1020'); shale, dark grey, laminated; fissile; only slightly dolomitic at best; minor kerogen only; irregular laminae and blebs of white crystalline calcite on bedding planes

310.9-312.1 m (1020-1024'); marlstone, dark brownish-grey, dolomitic

312.1-316.1 m (1024-1037'); shale, dark grey-brown to brown-grey; only slightly dolomitic; laminated; fissile; not too rubbled but does break; dolomite probably 2%, definitely less than 5%

316.1-319.7 m (1037-1049'); shale; slightly more dolomitic and harder than above; possibly 5% dolomite; 319.7 m - 5 cm sandstone band; light grey; fine to medium grained; quartz and feldspars; calcareous; hard

319.7-321.6 m (1049-1055'); shale, dark grey; laminated; fissile; minimum dolomite

321.6-322.5 m (1055-1058'); sandstone, light grey, fine grained, calcareous; hard; tight; grey shale laminae near top and base of zone

322.5-338.3 m (1058-1110'); shale, dark grey; laminated; fissile; only very slightly dolomitic at best; scattered sandstone laminae and occasional bed to 8 cm; sandstones fine grained; tight

338.3-338.9 m (1110-1112'); sandstone, light grey, fine grained; hard; tight; siliceous cement; laminae and interbeds of dark grey shale; slightly wavy laminae and irregular bed continuity [flood plain (?)]; bands immediately above and below of grey-brown dolomitic shale with slight odour on heating

338.9-340.5 m (1112-1117'); shale, dark grey and brown-grey; colour variable; scattered laminae and thin beds 0.5 cm

of possible volcanic ash near base

340.5-340.6 m (1117-1117.5'); sandstone, light grey, fine grained; tight; low angle fluvial cross-beds

340.6-341.1 m (1117.5-1119'); shale, dark grey; laminated; fissile; low dolomite

341.1-351.1 m (1119-1152'); sandstone, light grey, fine grained; hard; tight; numerous cross-beds and fluvial characteristics; numerous zones and laminae; dark grey shale; sandstone, mostly quartz, some feldspar recognized; siliceous

351.1-356.6 m (1152-1170'); shale, dark grey; occasional slight brown tinge; very finely laminated; fissile; rubbles easily; up to 10% dolomite content

356.6-357.5 m (1170-1173'); sandstone, light grey, as above

357.5-358.1 m (1173-1175'); shale, dark grey; as above

358.1-363.6 m (1175-1193'); sandstone and shale; interbedded; zone 15 to 30 cm thick of alternating lithologies; as above

363.6-364.8 m (1193-1197'); sandstone; as above; some cross-beds; fluvial to flood plain; thin cross-bedded zones; scattered shale laminae

364.8-373.1 m (1197-1224'); shale, dark grey; as above; with scattered beds; 10 to 23 cm of sandstone

373.1-376.1 m (1224-1234'); sandstone, grey; light green tinge at 375.2 m; low angle cross-beds; some slump structure; interbedded 15 to 23 cm zones of grey shale; green shale accompanies green sandstone interval; green shale is non-dolomitic

376.1-390.1 m (1234-1280'); shale, dark grey; laminated; fissile; very slightly to non-dolomitic; at 378.0 m zone of 8 cm green shale and 8 cm green sandstone scattered laminae to thin zone (0.6 cm) with crystalline pyrite, evident as rusty brown bands throughout the interval; occasional sandstone beds to 2.5 cm thick; at 383.4 m 3.8 cm green-grey massive dolomitic shale; at 387.7 m, 3.8 cm bed grey sandstone; fine grained; tight; cross-bedded

390.1-391.1 m (1280-1283'); sandstone, light grey, fine grained; hard; siliceous; laminae to 2.5 cm beds of dark grey shale; irregular slightly wavy bedding; no cross-beds

391.1-395.6 m (1283-1298'); sandstone and shale; alternating 2.5 to 15 cm zones; light grey quartz-feldspar; siliceous; slightly calcareous, dark grey laminae of fissile shale, very rubbly, very slightly dolomitic

395.6-414.5 m (1298-1360'); shale, dark grey; becoming less fissile and slightly harder downward; occasional pyrite on laminae; slightly dolomitic, occasional beds to 15 cm of light brown-grey very fine grained quartz sandstone with minor plant (wood) debris; almost silt size; slightly to non-rubblized

414.5-471.5 m (1360-1547'); shale, dark grey to brown-grey; laminated; fissile; not rubbled; fairly hard; only slightly dolomitic; numerous thin zones and laminae of light brown claystone which weathers rusty-orange; zone has some higher dips; some micro and a few slightly larger drag folds; has undergone lateral compression

471.5-474.6 m (1547-1557'); sandstone, light grey, fine to very fine grained; hard; massive; siliceous; traces of plant debris; bedding indistinct because of uniform grain size; some slump structures; flood plain wavy laminae made evident by dark grey clay; some interbeds of dark grey laminated shale

474.6-495.3 m (1557-1625'); shale, dark grey; laminated; sub-fissile; occasional plant debris; non-dolomitic

495.3-496.8 m (1625-1630'); siltstone, reddish-grey; massive; hard; very fine grained; siliceous; uniform; traces of plant debris

496.8-499.0 m (1630-1657'); shale to siltstone, medium grey to brown-grey; very fine grained quartz; traces of plant remains; albertite pod noted; fairly flat bedding planes; not fissile

499.0-511.1 m (1657-1677'); siltstone, light grey-brown; weathers brown; very fine grained; quartz; slightly dolomitic; siliceous; hard; tight; sandstone at base

511.1-512.1 m (1677-1680'); marlstone, dark brown; slow dolomite reaction in hot acid; smokes, glows and gives off odour when heated; laminated; hard; approaches a blocky laminated type but lesser laminae than required to be good blocky zone; slickensides on some bedding planes

512.1-512.7 m (1680-1682'); siltstone, light brownish-grey; hard; massive to some laminated bedding; argillaceous; traces of woody debris; patches of dark brown kerogen bearing shale

512.7-514.2 m (1682-1687'); marlstone; with numerous interbedded siltstone laminae and thin bed (0.3 cm); up to 5° wavy dip; very slight dolomite reaction in acid; slickensided; laminated but does not split easily

514.2-598.0 m (1687-1962'); sandstone, light grey, very fine grained, quartzose; in part grading to siltstone; very

hard; slightly dolomitic with partings of brown organic shale; shale decreases downward and basal 6 m is virtually all sandstone; basal 1.5 m has minor very fine, porosity saturated by heavy oil residue

598.0-608.1 m (1962-1995'); marlstone, dark greyish-brown; fair to good hot acid reaction; very finely laminated; sub-fissile to hard but not really blocky; odor on heating; hard to split to a good thin edge; several zones to 5 cm thick of massive brown dolomite marlstone

608.1-615.1 m (1995-2018'); marlstone; finely varved; approaching blocky type; smokes and glows when heated

615.1-617.8 m (2018-2027'); marlstone; as above; some massive zones; slight decrease in varving; a couple of zones of depositional slump texture, but these are uncommon, sandy zone at 616.3 m

617.8-641.3 m (2027-2104'); marlstone, dark brownish-grey; mostly sub-blocky type; fair laminations and varves but does not split easily on bedding planes; hard; scattered massive marlstone zones; at 626.1, 634.0 and 635.8 m, sandstone zones, approximately 30 to 45 cm thick; fine grained; brown stained; no oil shale evidence for high assay readings over lower interval - probably included the oil saturated sandstones

641.3 m (2104'); T.D.

AtlanticRichfield Rosevale 1

30° off vertical towards S20°E (magnetic)
elevation: 149.4 m

0.0-43.3 m (0-142'); not retained

43.3-43.6 m (142-143'); shale, light grey; finely laminated; silty

43.6-44.5 m (143-146'); marlstone, light brown; some zones of kerogen laminations but generally discontinuous, massive, silty, a few very thin sandstone interbeds; generally wavy laminations where present; no fissility

44.5-44.8 m (146-147'); sandstone, light grey; quartzose, fine grained; massive; calcareous cement

44.8-45.1 m (147-148'); shale, light grey, finely laminated, silty

45.1-52.1 m (148-171'); core missing

52.1-57.6 m (171-189'); marlstone, brown; laminated to some finely varved in high grade zone; numerous thin interbedded dolomitic sandstone lenses to laminae; marlstone in part silty; high grade zones contain abundant laminae but no significant fissility; remains a massive dolomite type

57.6-83.8 m (189-275'); core missing

83.8-110.6 m (275-363'); siltstone, dark to medium brownish-grey, quartzose, dolomitic; interbedded with light brown fine grained quartzose sandstone and dolomite; light brown in part silty and argillaceous, some possible kerogen flecks and fine laminae but no significant laminated organic zones; 108.5-110.6 m - mostly marlstone with fine wavy kerogen laminae

110.6-113.4 m (367-372'); sandstone, medium brown, fine grained, quartzose; massive; siliceous

113.4-114.9 m (372-377'); marlstone, brown, finely laminated; not varved; numerous laminae of dark brown siltstone

114.9-118.9 m (377-390'); sandstone, light to medium brown, quartzose; some feldspar (?); siliceous; interbeds of dolomite marlstone

118.9-120.7 m (390-396'); marlstone; siltstone interbedded; fair kerogen laminae; dark greyish-brown

120.7-124.4 m (396-408'); sandstone, medium brown, fine grained; hard; quartz and possible feldspar; dolomitic cement;

basal 0.3 m contains large angular rip-up clasts of laminated marlstone

124.4-128.6 m (408-422'); sandstone, light to medium brown, very fine grained, quartzose, dolomitic; numerous discontinuous brown organic laminae to flecks; some zones grade to sandy marlstone

128.6-130.8 m (422-429'); marlstone, light to medium brown; sandy, up to 30% quartz grains; wavy discontinuous kerogen laminae

130.8-134.1 m (429-440'); sandstone, medium brown, quartz, fine grained; some small pebble zones; marlstone matrix and grading to some sandy marlstone

134.1-136.9 m (440-449'); marlstone, medium-dark brown, laminated; fair to good continuous wavy kerogen laminae; not fissile; hard; silty; some sandy laminae; becomes sandier downward and grades to sandstone

136.9-154.5 m (449-507'); sandstone, medium brown, fine grained, quartzose; massive, with irregular wavy dark brown zones of siltstone; some argillaceous to marlstone zones; approximate dip, 10° to core axis

154.5-164.6 m (507-540'); sandy marlstone; grading to zones of dolomitic sandstone and some kerogen laminated silty marlstone; zones of darker grey hard siltstone; occasional good kerogen zones

164.6-165.2 m (540-542'); sandstone

165.2-165.8 m (542-544'); silty marlstone, medium brown; abundant fine continuous slightly wavy kerogen laminae

165.8-167.6 m (544-550'); sandstone

167.6-178.0 m (550-584'); marlstone, brown, laminated; ranges poor to fair dark brown lamination development; sandy at top grading down to silty at 170.4 m and remaining silty, probably argillaceous; grades down to shale

178.0-193.5 m (584-635'); shale, grey, very slightly dolomitic; chunky to some fissile zones; then interbeds to laminae; light brown dolomite gives some colour laminated zones; dolomite zones usually silty; sandstone bed at 191.4 m, siltstone zone at 193.2 m

193.5-230.0 m (635-755'); not available for logging

230.1-242.3 m (755-795'); shale, medium grey; sub-laminated; in part good fissility; non to very slightly dolomitic, occasional laminae to very fine interbeds to greyish-brown

argillaceous dolomite

242.3-244.4 m (795-802'); marlstone-shale; finely interbedded marlstone in sands; some zones with concentrated kerogen laminae

244.4-250.0 m (802-820'); siltstone-shale-marlstone, interlaminated; some sandstone lenses; marlstone decreasing downward as fissility increases (shale content) below 246.0 m; zone has good laminated appearance because of the interbedding of rock types

250.0-253.9 m (820-833'); siltstone, marlstone, minor shale; interbedded and laminated as above but increased marlstone content and kerogen laminae

253.9-256.9 m (833-843'); shale; grey, fissile; a few blockier sections with sandy to silty beds and minor marlstone laminations

256.9-257.9 m (843-846'); sandstone, siltstone, marlstone; interlaminated

257.9-260.9 m (846-856'); shale; minor marlstone and siltstone beds; fissile

260.9-264.3 m (856-867'); marlstone, brown; sandy to silty, variation provides colour banding; only minor kerogen laminae grades down to shale

264.3-269.1 m (867-883'); shale, light brownish-grey; fissile; zone of medium brown silty dolomite (massive, no kerogen) at 265.2 m

269.1-274.3 m (883-900'); marlstone, light brown, silty; very fine uniform kerogen laminae, good quantity but insufficient to be defined as varved; minor small microfold and faults but not of major importance; will not split on bedding planes; smokes but does not ignite

274.3-274.9 m (900-902'); sandstone, light brown, quartzose, fine grained, dolomitic; laminated with darker brown marlstone bands

274.9-279.5 m (902-917'); marlstone, light greyish-brown to brown; banded; increasing argillaceous content downward; some silt content, decreasing downward as clay increases

279.5-288.3 m (917-946'); shale, light brownish to greenish-grey to grey; laminated; in part dolomitic; fissile

288.3-291.7 m (946-957'); sandstone, brown to greyish-brown, fine to medium grained; scour and fill textures into the shale beds at 288.6 m

291.7-292.0 m (957-958'); siltstone, grey to brownish-grey, laminated, dolomitic; in part grades to silty dolomite with sandstone lenses; sandstones are siliceous

292.0-293.2 m (958-962'); sandstone, quartzose; brown; oil stained

293.2-296.3 m (962-972'); siltstone

296.3-299.6 m (972-983'); sandstone

299.6-300.2 m (983-985'); siltstone

300.2-300.8 m (985-987'); sandstone

300.8-303.3 m (987-995'); siltstone, dolomitic, brownish-grey; banded

303.3-303.9 m (995-997'); sandstone, dolomitic; brown

303.9-304.5 m (997-999'); dolomite-siltstone mixture; some kerogen, discontinuous laminae, indeterminant fossil replacement by pyrite

304.5-311.8 m (999-1023'); shale, light greenish to slightly brownish-grey; chunky to some fissile; very hard; very slightly calcareous; colour distinctly different from uphole shale zones

311.8-314.2 m (1023-1031'); siltstone, shale, marlstone; interlaminated; obvious kerogen laminae

314.2-355.1 m (1031-1165'); shale, medium brownish-grey; slightly dolomitic; chunky; generally no fissility; hard; massive; non-directional slickensides

355.1 m (1165'); T.D.

AtlanticRichfield Urney 1

45° off vertical towards N45°W (true)
elevation: 167.4 m

8.5-9.1 m (28-30'); quartzite, light brownish-grey, massive

9.1-24.4 m (30-80'); shale, light grey, massive chunky to sub-laminated, calcareous; scattered very fine carbonaceous debris; variably grades to claystone; many zones of missing core but intervening lithology inferred from core and AtlanticRichfield lithology log

24.4-63.4 m (80-208'); marlstone, brown, dolomitic, argillaceous; laminated with clay laminae and shaly beds; calcareous in upper few metres which are gradational downward from shale; numerous light to pale brown fine grained quartz silt laminae and thin beds outline bedding which is uniform and slightly wavy parallel throughout; generally composed of dolomite, clay, very fine quartz silt and scattered brown kerogen laminae; no good continuous zones of kerogen content; in part exhibits structural brecciation and also some possible sedimentary slump; some beds grade to massive siltstone; some small varved intervals due to the kerogen laminae

63.4-72.8 m (208-239'); marlstone, brown, well laminated; hard; approaching varved; breaks on laminae; dolomite; argillaceous; slightly silty; 66.4-72.2 m - brecciation and contortion; tight folds; calcite fracture filling

72.8-78.0 m (239-256'); marlstone, brown; decreased kerogen laminae from above; generally massive and hard; minimum cleavage on bedding planes although sufficient kerogen present to define the laminations; silty; 73.8-74.1 m - dolomite, sandy, quartz to 40%

78.0-78.9 m (256-259'); sandstone, light brown, quartzose, fine grained; dolomite cement; massive

78.9-107.3 m (259-352'); marlstone, brown, good colour laminated; no significant kerogen amount; silt laminae and lenses also provide colour banding; dolomitic; argillaceous; 80.5-80.8 m - light grey to brown dolomitic quartzose, fine grained massive hard sandstone; 86.6-87.5 m - folded and brecciated; 90.5-90.8 m - sandstone with marlstone interbeds; 102.1-107.3 m - laminae decrease downward

107.3-112.2 m (352-368'); marlstone, medium brown to greyish-brown; very argillaceous, silty and with silt laminae; decreasing kerogen laminae and massive appearance with only faint to no varved appearance; discontinuous kerogen flecks; in part brecciated with calcite infill; grades down to (?); 106.1-107.9 m - some fairly good lamination,

contorted

112.2-190.5 m (368-625'); shale is medium grey to brownish-grey, dolomitic; silty; massive to sub-fissile; scattered zones 2.5 to 3 cm thick of dark brown dolomitic siltstone; core zone rubbled from coring but no slickensides in evidence of structural deformation; occasional zones with minor interbedded intervals of dolomite, massive to varved, with apparent kerogen laminae in the minor part of interval; 133.8-135.9 m - slickensided; 136.6-137.8 m - slickensided; 142.0-145.7 m - badly rubbled, mostly slickensided; 146.3-152.4 m - rubbled, lesser slickensided; 152.4-154.2 m - finely laminated, silt laminae to thin beds; 156.1-162.8 m - high angle (to core), considerable dip variation, probable fault zones, rubbled; 162.8-168.2 m - blockier, silt zones, dolomite beds; 166.4-167.6 m - some better laminated with mudstone varves; 168.2-172.8 m - rubbled; 172.8-177.7 m - blockier, silt zones present, rubbled, dolomitic laminae; 177.7-190.5 m - badly rubbled, slickensided; 188.4-189.6 m - extreme slickensided

190.5-226.2 m (625-742'); shale, light to medium brownish-grey; very slightly dolomitic; chunky, very fine laminae to some interbeds (0.3 cm) light brown dolomite; no evidence of significant kerogen laminae; 210.0, 213.4 m - minor slickensides on shear zones; 221.3-226.2 m - downward increase in dolomite marl continuous laminae to thin beds

226.2-236.8 m (742-777'); marlstone, medium to dark brown, laminated to almost varved; dark brown laminae of kerogen and silt

236.8-255.4 m (777-838'); shale, brownish-grey to greyish-brown, dolomitic; interbedded and laminated with brown silty marlstone with little evidence of kerogen; hard

255.4-271.3 m (838-890'); marlstone, dolomitic, brown, argillaceous; minor kerogen laminae at best; not silty; clay to shale interbeds and laminae; hard

271.3-291.7 m (890-957'); dolomite, brown; organic partings from pressure solution during lithification but essentially low kerogen content; massive to only scattered laminated zones to thin bedding; grading to brown dolomitic shale, massive, in lamination; some brown quartz sandstone zones with rip-up clasts of dolomite to marlstone; resembles conglomerate at near T.D. but all much finer grained here; rip-up clasts extremely angular, most evident in basal 3 m of core; 281.6-284.1 m - silty, fine grained quartz, massive

291.7 m (957'); T.D.

APPENDIX 2

CORE SAMPLE DESCRIPTIONS

AtlanticRichfield Albert Mines 1A

1: 240.8 m (790'); 78.0 l/t; dark-brown microlaminated dolomitic marlstone; continuous well defined organic laminae; bands of numerous laminae separated by bands of laminae-free marlstone, the latter exhibiting fine dolomite grains (tan colour on weathered surface); quartz filled fractures parallel laminae, regular, even fracture of the core parallels bedding

2: 249.6 m (819'); 79.6 l/t; dark-brown massive silty marlstone; discontinuous "feathers" of organic rich bands impart a preferred orientation; fine dolomite grains (tan colour on weathered surface) noted; fine quartz grains (lesser quantity) than dolomite) noted; core fractures approximate bedding and are slightly irregular

3: 292.0 m (958'); 65.9 l/t; brown massive and in part microlaminated dolomitic marlstone; portions exhibit continuous organic laminae but the sample is mainly massive with only disseminated organics or at best discontinuous organic laminae; portions silty to fine sand; core fractures approximate the bedding plane with slight irregularities

4: 305.1 m (1001'); 56.7 l/t; dark-brown irregularly laminated and discontinuously laminated dolomitic marlstone (in part, silty); organic laminae in less silty portions are contorted as opposed to discontinuous in silty portions; contact between silty portion and true marlstone exhibits "rip-up" breccia; core fractures across bedding planes

Canadian Occidental Petroleum Albert Mines 2

1: 20.4 m (67'); 97.2 l/t; marlstone, dark brownish-grey to some greyish-brown; slight dolomite reaction; very finely laminated; very fissile, numerous slickensides along laminations, dolomite reaction may be low because of kerogen content; 60° dip; structural deformation, slickensides on bedding laminae; laminae only sporadically evident as dark brown probable kerogen layers; although fissile, thin edges difficult to obtain, smokes and glows easily but lights with difficulty

2: 44.8 m (147'); 28.4 l/t; marlstone, medium brownish-grey, slightly to quite dolomitic grading to dolomite marlstone; very finely laminated; no fissility; massive rich irregular rough breakage approximately following bedding; fissility 5% very fine quartz, silt; slight odor when heated, does not smoke but good thin edges difficult to create; generally massive but the faint laminae in part appear related to kerogen; generalized dip about 30°; several microfaults filled by thin laminae of white crystalline calcite; some variations at dip related to contortions tied to the microfaults

3: 69.2 m (227'); 65.5 l/t; marlstone, medium grey to brownish-grey; scattered patches; slow dolomite reaction; massive; hard; no fissility at all; only very poor scattered faint laminations defined by possible kerogen layer, discontinuous; almost impossible to obtain thin ridge edge; odor on heating with minor smoke; fine muscovite flakes throughout; dip indeterminate because of massive character; scattered fine carbonaceous plant debris

4: 89.9 m (295'); 148.9 l/t; marlstone, medium to dark greyish-brown, very finely laminated, "varved" with many dark brown kerogen laminae; splits on bedding planes with good possibility, but stays together well when cored; microcrystallinity of dolomite evident at x50 power; gold dolomite reaction in hot acid; kerogen layers apparent in residue; slightly wavy uniform continuous laminae; uniform dip at 60°; easy to create a thin edge, lights easily; low density very evident

5: 107.9 m (354'); 93.0 l/t; marlstone, medium to dark greyish-brown to some brownish-grey, in part very finely laminated, varved alternating with more massive beds to ½ inch; where present, laminae are dark brown kerogen; splits in bedding where laminae present, breaks irregularly across massive zone; laminae continuous where varved but becomes discontinuous in mere massive intervals; some odor on breaking; some irregular slickensides; smokes easily but hard to ignite and then edges somewhat difficult to obtain; average 60° uniform dip; fairly light weight, but heavier than above

5A: 110.9 m (364'); 44.2 l/t; marlstone, medium grey, very slight brownish tinge; hard; very fine faint slight wavy almost mottled lamination, very poorly defined; no fissility or cleavage; very irregular breakage; slow steady dolomite reaction; probably high dolomite content; kerogen not concentrated in laminae, just disseminated; some clay content; general slightly wavy 70° uniform dip; impossible to get good thin edge; odor on heating; heavier weight - move normal for dolomite marlstone

6: 125.0 m (410'); 118.8 l/t; marlstone, medium brownish-grey with varve-like laminae of dark brown kerogen; very finely varved, laminae continuous; very fissile but must be lit to split, quite massive considering the fissility; calcite vein (0.3 cm) parallels bedding; light weight; smokes and burns; some of sample grades to slightly heavier less fissile type; uniform 45° dip; dolomitic

6A: 128.6 m (422'); 100.1 l/t; marlstone, medium grey to dark brown; laminated; too course bedding to be defined as varved; extremely fine dolomite microcrystallinity evident at x50 power; some discontinuity of laminae; massive, does not break on laminae planes; very slow acid reaction; has some definite kerogen laminae; some of the organic laminae weather to a light orange colour; fairly light weight; average 45° dip; smokes; difficult to get thin edge

7: 140.8 m (462'); 65.1 l/t; marlstone, medium to dark brownish-grey; not well laminated; kerogen seems to be present but is in more discontinuous flecks rather than as continuous laminae; breakage occurs best in brown slickensided kerogen laminae; uniform 70° dip; hard; smokes easily but does not light except on very thin edge

8: 166.4 m (516'); 162.2 l/t; marlstone, dark brown; microcrystalline dolomite under x50 power; good dolomite acid reaction; hard, medium weight; wavy laminae, somewhat irregular and sometimes discontinuous; odor on breaking, irregular breakage, does not follow laminae; hard to get good thin edge; general 80° dip

9: 178.6 m (586'); 140.5 l/t; marlstone, dark brown, massive, very poor, indistinct, irregular wavy laminae; microcrystallinity of dolomite evident under x50 power; scattered fine grained rounded quartz sandstone (<5%); traces of carbonaceous debris; 50° dip; odor on breaking; smokes easily; hard to get thin edge; rust coloured weathering patches around blebs of albertite with free sulphur and selinete(?) crystals; the presumed albertite appears graphitic

9A: 238.0 m (781'); 38.8 l/t; shale, medium grey, laminated; fissile; splinters; only very slight traces of dolomite; no apparent kerogen content or humic phase

10: 241.1 m (791'); 100.9 l/t; shale, dark brownish-grey, faintly laminated; hard; massive; non-fissile; a few faint laminae of possible kerogen; some plant debris; slight odor on breaking; odor on heating, smokes, discolours; approximate 45° dip; only very limited dolomite-acid reaction

11: 244.4 m (802'); 50.5 l/t; shale, medium grey, slight brownish tinge; laminated; sub-fissile, some hackly breakage; essentially non-dolomitic; 35° dip; badly rubbled

Canadian Occidental Petroleum Albert Mines 4

1: 415.1 m (1362'); 27.9 l/t; shale, medium grey to brownish-grey; massive, chunky, no apparent lamination or fissility; in part slightly dolomitic; minor plant debris and scattered small smooth shelled ostracods; approximate 30° dip; scattered shark teeth (?) and scales

2: 431.0 m (1414'); 126.8 l/t; marlstone, medium brown; generally finely laminated to varved with individual laminae of brown kerogen, some zones of discontinuous kerogen; approximate 40° dip with some minor brecciation and contortion of better varved zones; a few silt (quartz) laminae; scattered elongate pyrite blebs and dolomite marl; some irregular slickensides in kerogen planes, especially in contorted zones

3: 431.9 m (1417'); 142.6 l/t; marlstone; as above but with slightly greater amount of irregular patchy brownish-grey zones containing greater clay content; appears to have slightly less kerogen lamination, with more discontinuous zones; no contorted zones, lacks any significant slickensides; dip 30°; scattered fine, thin, slightly elongated pyrite blebs and lenses on laminae surfaces

4: 445.9 m (1463'); 22.5 l/t; marlstone, medium to dark greyish-brown; massive, hard; bedding evident by extremely fine, discontinuous, uniformly laminated organic debris, probably kerogen, but some apparent layers of wood or plant fragments; irregular rough breakage as no fissility present; significant odor on breaking; contains thin bed (1.3 cm) of light grey quartzose sandstone containing brown oil or kerogen splotches and some apparent carbonaceous debris; approximate 50° dip

5: 456.2 m (1499'); 134.7 l/t; marlstone; medium brown with numerous bands and zones containing continuous dark brown kerogen laminae; splits on kerogen laminae but not sufficiently to be classed as easily fissile; some zones with fine discontinuous flat-lying kerogen flakes, these zones are more massive and do not split in bedding planes; scattered flat-lying black carbonaceous debris; still massive marlstone but partially approaching papery; 50° dip; dolomitic

6: 456.2 m (1497'); 65.5 l/t; marlstone, dark to medium brown, dolomitic; scattered mica flakes; extremely varved; fissile but holds together fairly well; blocky laminated type; high angle bedding to 85°; badly contracted, and much slickensided; shiny, greasy, medium brown on slickenside planes which are often fractured and displaced; can be split to thin edge; ignites

7: 465.4 m (1527'); 59.2 l/t; marlstone, medium grey to greyish-brown; very finely laminated to colour varved; generally

hard, splits smoothly on slickenside planes which follow kerogen laminae or may cross laminae at 5° angle to bedding; discontinuity of brownish laminae as kerogen discontinuously present; occasional carbonaceous debris; does not split easily to a thin edge; massive marlstone type, although splitting occurs along smooth planes; there is insufficient fissility to be papery type, 50° dip

8: 474.9 m (1558'); 102.2 l/t; marlstone, medium to dark brown; zones of massive dolomite marlstone with fairly continuous to streaky kerogen interbedded with zones of finely varved papery marlstone; zones micro-faulted and brecciated by fault movements; curly contorted; interbedding of two quality types; 70° dip; thin edges smoke and burn

9: 476.4 m (1565'); 82.6 l/t; marlstone; as above but with slightly better papery characteristics; some contortions; some slickensiding on kerogen planes; a few quartz grain silt laminae to very thin interbeds; most kerogen laminae continuous across core; thin edges smoke and burn; 60° dip

10: 484.6 m (1590'); 108.0 l/t; marlstone, brown; massive type with numerous thin laminated papery zones; structurally broken contorted and curled on the paper laminae (approximately 10% of sample is paper); massive, has mostly discontinuous flecks of kerogen; occasional carbonaceous fragments; some very fine quartz silt content; possible blebs of albertite; 60 to 70° dip average

11: 495.6 m (1626'); 33.4 l/t; marlstone, brown to brown-grey; massive; only minor kerogen flecks and occasional paper zones to laminated; interbedded fine grained grey hard quartz sandstone lenses; 80° dip; badly disturbed but not extensively slickensided

12: 502.3 m (1648'); 57.1 l/t; marlstone; basically as above; some contorted zones on kerogen laminae; possibly increasing quartz laminae bedding; much distorted around sandstone lenses and irregular blebs and may be partly depositional slump; 70° to 80° dip; some slickensides which exhibit darker grey rather than brown as clay content may be increasing

13: 517.6 m (1698'); 20.4 l/t; shale, grey; very slightly micaceous; poorly laminated; chunky; rubbled, some grey slickensides; no evidence of kerogen laminae or of carbonaceous debris

Canadian Occidental Petroleum Albert Mines 5

1: 78.0 m (256'); 155.5 l/t; medium brown finely laminated dolomitic marlstone; laminae not entirely continuous, gently undulating; non-laminated zones appear to be clay rich, i.e. weathered to a light grey colour; core fracture approximates the bedding; minor number of plant fragments; shark (fish) scales and tooth noted

2: 142.6 m (468'); 59.6 l/t; dark brown fissile microlaminated dolomitic marlstone; continuous regular laminae; core breaks readily into thin plates parallel to bedding; plates smoke and burn independently upon heating

3: 146.3 m (480'); 23.8 l/t; light grey-brown limestone; approximately 50% of the sample exhibits varving and is likely dolomitic with some organic content; a small portion of the sample (5%) burns upon ignition; the limestone contains some plant material; sample exhibits some fissility and breaks into 2 mm plates

4: 172.2 m (565'); 37.1 l/t; dark brown finely laminated dolomitic marlstone; regular, continuous laminae; numerous calcite laminae; approximately 50% of sample consists of thin plates exhibiting slickensides which do not burn but smoke upon heating

5: 181.4 m (593'); 36.3 l/t; dark brown massive marlstone, in part dolomitic siltstone; core breaks into "blocks"; no bedding; minor percentage (1-2) of disseminated fine plant fragments; slightly micaceous

6: 192.3 m (631'); 83.8 l/t; dark brown finely laminated fissile dolomitic marlstone; burns independently upon heating; brown slickensided bedding planes; weathered surface exhibits alternating tan, dark grey and white bands

7: 197.8 m (649'); 123.4 l/t; dark brown microlaminated marlstone fractures approximate bedding planes and produces massive "blocks"; organics disseminated as well as forming continuous although extremely fine laminae; slightly calcareous matrix in places

8: 202.1 m (663'); 105 l/t; dark brown finely laminated fissile dolomitic marlstone; calcite beds (0.5 mm) present; although fissile, core tends to break into plates no less than 0.5 cm in thickness; laminae are continuous

9: 202.1 m (683'); 132.6 l/t; dark brown fine to microlaminated slightly fissile dolomitic marlstone; laminae are continuous; although core is fissile plates tend to be of irregular thickness due possibly to structural contortion of the sample evidenced by slickensides and bedding deformation; plates burn independently upon heating

10: 233.2 m (765'); 115.5 l/t; dark brown microlaminated fissile dolomitic marlstone; laminae are continuous although some laminae undulate slightly and terminate one into the other

11: 238.4 m (782'); 83.0 l/t; dark brown finely laminated fissile dolomitic marlstone; laminae are continuous; brown slickensides on bedding planes; burns freely upon heating; portions exhibit fracture across laminae

12: 253.0 m (830'); 167.2 l/t; dark brown microlaminated slightly fissile dolomitic marlstone; laminae are continuous; 60% of sample exhibit undulating laminae and slickensides

13: 256.6 m (842'); 148.9 l/t; dark brown microlaminated dolomitic marlstone; laminae are continuous; core fractures across laminae although some breaking parallel to bedding noted

14: 276.0 m (876'); 102.2 l/t; dark brown fine to microlaminated dolomitic marlstone; laminae are continuous; core fractures across laminae, although some breaking parallel to bedding noted

15: 268.8 m (882'); 262.7 l/t; dark brown fine to microlaminated dolomitic marlstone; sample exhibits some degree of fissility in that the sample parts into thin laminae in places although the bulk of the sample breaks down to discs approximately 2 cm in thickness; laminae are continuous, well developed and control sample parting; shark's tooth noted

16: 279.5 m (917'); 111.3 l/t; dark brown fine to microlaminated dolomitic marlstone; sample parts parallel to laminae to some degree but produces hachy fracture and tends to fracture across laminae; laminae are continuous, well developed; organic laminae not continuous on microscopic scale

17: 282.5 m (927'); 60.5 l/t; medium brown massive dolomitic marlstone; numerous ostracods; no bedding evident; irregular blocky fracture; slightly silty

18: 285.9 m (938'); 50.5 l/t; medium brown massive dolomitic marlstone; some ostracods; no bedding evident; irregular blocky fracture; slightly silty

19: 345.9 m (1135'); 84.7 l/t; dark brown grossly laminated silty dolomitic marlstone; organic laminae are continuous; blocky fracture very crudely approximates laminae; weathered dolomite grains (tan coloured) impart a mottled appearance to sample

20: 363.9 m (1194'); 90.1 l/t; dark brown massive dolomitic marlstone; blocky fracture; weathered dolomite grains (tan coloured) impart a very finely disseminated mottled

appearance to sample

21: 399.9 m (1312'); 28.8 l/t; dark brown finely laminated dolomitic marlstone; laminae, although continuous are indistinct and contain little organic material; laminae appear to be bands of lesser disseminated organics; blocky fracture

22: 414.5 m (1360'); 75.9 l/t; dark brown massive dolomitic marlstone; organic rich discontinuous laminae; blocky fracture

23: 447.1 m (1467'); 72.6 l/t; dark brown massive dolomitic marlstone (25%) and dark brown microlaminated dolomitic marlstone (75%); both exhibit blocky fracture; the massive portion exhibits disseminated organics; the laminated portion exhibits discrete continuous organic laminae

24: 487.7 m (1600'); 33.4 l/t; dark brown finely laminated to massive dolomitic marlstone; many of the thicker laminae (≅2 mm) consist of silt and disseminated organics; blocky fracture; shaley portions exhibit little or no organics

25: 504.1 m (1654'); 88.0 l/t; dark brown microlaminated dolomitic marlstone; soft sediment brecciation and laminae crenulation; organic laminae, although grossly continuous, consist of bands of disseminated organics; blocky fracture

26: 535.2 m (1756'); 44.6 l/t; dark brown massive dolomitic marlstone; "rip-up" breccia, angular fragments of microlaminated dolomitic marlstone in a massive matrix; angular fracture of core; marlstone fragments are aligned, imparting a preferred orientation; areas in core tend towards a silt and fine sand

27: 591.6 m (1941'); 43.8 l/t; dark brown massive dolomite; angular fragments of laminated dolomitic marlstone; blocky fracture

28: 598.0 m (1962'); 85.5 l/t; dark brown partly laminated dolomitic marlstone; portions exhibit very continuous organic rich laminae, although the bulk of the sample exhibits discontinuous crenulated laminae; sharp regular fracture at right angle to core axis and across bedding; portions of the sample are silty

29: 606.6 m (1990'); 22.9 l/t; dark brown to grey massive silty dolomite; portions of the sample exhibit crenulated discontinuous laminae; minor disseminated pyrite; sharp regular fracture at right angle to the core axis

30: 652.3 m (2140'); 72.6 l/t; dark brown massive silty dolomitic marlstone; exhibits preferred orientation but no laminae; organics consist of discontinuous "feathers"; quartz rich fragments (minor quantity) within the marlstone; sharp

fracture at right angles to the core axis

31: 656.8 m (2155'); 53.8 l/t; dark brown massive silty dolomitic marlstone; exhibits preferred orientation but no laminae; organic "feathers"; fractures 90° at right angles to the core axis

32: 664.5 m (2180'); 31.7 l/t; dark brown to grey massive dolomitic marlstone; microlaminations permeate sample but are discontinuous and in part crenulated; fracture approximates bedding; portions tend towards a silt

33: 710.2 m (2330'); 70.4 l/t; dark brown to grey massive dolomite; discontinuous organic laminae, low enough percentage so as not to exhibit discrete laminations; regular at right angles to the core axis

34: 237.6 m (2420'); 69.2 l/t; dark brown massive to microlaminated dolomitic marlstone, in part silty; degree of lamination varies from discontinuous to continuous crenulated

35: 743.7 m (2440'); 26.3 l/t; dark brown to grey massive dolomitic marlstone with massive dolomite (10%); marlstone exhibits fine discontinuous organic laminae; fractured core

Canadian Occidental Petroleum Albert Mines 6

1: 68.6 m (225'); 47.5 l/t; dark brown, finely laminated fissile dolomitic marlstone; weathered surface exhibits tan coloured laminae in a dark grey ground mass; carbonaceous plant fragments on the bedding planes; plates of "shale" exhibit marginal ignition upon heating

2: 77.1 m (253'); 49.6 l/t; dark brown finely laminated fissile dolomitic marlstone; fissility is disrupted by sample fracturing due to a combination of reduced continuity of laminae and structural deformation; "shale" plates noted above are not continuous across the core; plates of sample material smoke and make a "popping" sound upon heating

3: 81.7 m (268'); 35.4 l/t; dark brown, finely laminated fissile dolomitic marlstone; gypsum band, approximately 3 to 5 mm in thickness; alternating laminae of tan and dark grey on weathered surface; no burning upon heating, sample smokes and makes a popping sound with smoke and distinctive oil odor; portions of the sample exhibit contorted bedding and in places are slickensided, imparting a rubbled appearance to those portions of the sample

4: 91.5 m (300'); 71.7 l/t; dark brown finely laminated fissile dolomitic marlstone; well defined regular laminae; fissility, although present is not very well developed as the sample tends to break into blocks of core approximately 1.5 to 2 cm in thickness; laminae of tan colour weathered dolomite present

5: 103.6 m (340'); 91.3 l/t; dark brown microlaminated dolomitic marlstone; core fractures along laminae into blocks of 1 to 5 cm in thickness; laminae consist of alternating black and light grey and tan 0.1 mm thick bands; approximately half of the bands are not continuous across the core but fold and contort within the core

6: 121.9 m (400'); 65.9 l/t; dark brown massive dolomitic marlstone; bedding planes marked by discontinuous waved varving; blocky fracture; grain size tends towards a silt

7: 132.0 m (433'); 111.8 l/t; dark brown microlaminated dolomitic marlstone; core fractures along laminae into blocks of 1 to 5 cm in thickness; laminated appearance imparted by alternating black and light grey and tan 0.1 mm thick bands; laminae are both continuous and contorted i.e. the sample is made up of both continuous regular tightly contorted micro-laminae

8: 143.6 m (471'); 96.7 l/t; dark brown discontinuous laminated to massive dolomitic marlstone; core fractures approximately on bedding planes into blocks of 2 to 7 cm in thickness; although portions of the sample exhibit continuous micro-lam

the bulk, although laminated, is given that appearance by discontinuous lenses and laminae

9: 153.3 m (503'); 48.8 l/t; dark brown microlaminated dolomitic marlstone; core fractures along laminae into blocks of 3 to 5 cm in thickness; laminated appearance imparted by alternating black and tan 0.1 mm thick; continuous well developed laminae are offset by minor fracturing; contorted laminae although noted, make-up only a portion of the sample; a very small portion (2-3%) of the sample exhibits fissility

10: 182.3 m (598'); 58.8 l/t; dark brown discontinuously laminated dolomitic marlstone; discontinuous laminations are imparted by thin elongated bands of plant (carbonaceous) matter and elongated dolomite grains and lenses; core fractures approximate the bedding planes, forming blocky "chunks" approximately 2 to 7 cm in thickness

11: 185.3 m (608'); 62.6 l/t; dark brown discontinuously laminated dolomitic marlstone; gently waved thin laminae are distinct but are not continuous; laminae consist of alternating bands of black, medium brown and tan colouration; core fractures approximates the bedding planes

12: 188.1 m (617'); 61.7 l/t; dark brown microlaminated and discontinuously laminated dolomitic marlstone; sample consists approximately of 50% continuous microlaminated material and gently waved discontinuously laminated material; continuously laminae cut the entire cross section of the core whereas the discontinuous laminae impart a bedding attitude but the laminae of dark grey and light grey colouration do not cut the entire core

13: 194.8 m (639'); 33.8 l/t; dark grey to brown poorly laminated dolomitic marlstone; microlaminae are present although they are not distinct and core tends to fracture randomly; sample presents a massive appearance; dolomite circles (spheres) appear as replacement of algae growths

14: 199.3 m (654'); 62.1 l/t; dark brown discontinuously laminated dolomitic marlstone; lenses and fragments of microlaminated material, organics and dolomite in a very poorly laminated almost massive ground mass; laminations are very poorly developed and discontinuous; core fractured into 6 cm long blocks

15: 204.2 m (670'); 157.2 l/t; dark brown discontinuously laminated dolomitic marlstone; waved discontinuous microlaminae of black organic material impart gently undulating laminated appearance; small portion (5-10%) of the sample exhibits continuous microlaminated appearance; core fractures along bedding planes in more continuously laminated portions but cross cuts bedding planes in discontinuous portions

16: 214.9 m (705'); 43.8 l/t; dark brown massive and indistinctly microlaminated dolomitic marlstone; approximately 60% of sample exhibits no laminae and tends to be silty; approximately 40% exhibits indistinct but continuous microlaminae; entire sample contains carbonaceous plant material

17: 237.7 m (780'); 55.5 l/t; dark brown sandy (in part laminated) and microlaminated dolomitic marlstone; approximately 60% of sample is quartz grain bearing exhibiting few laminae although some black coloured (organic) thin laminae noted; 40% of sample is continuously microlaminated; two sand beds (0.5 to 2 cm) are included in the microlaminated portion of the sample

18: 242.0 m (794'); 193.9 l/t; dark brown fine to microlaminated dolomitic marlstone; regular, continuous laminae and contorted laminae both present; core fractures (close to bedding) into blocks of 6 to 8 cm in thickness

19: 246.9 m (810'); 28.8 l/t; dark brown massive dolomitic marlstone; discontinuous laminae ("feathers") of organic material outline what bedding is visible although bedding is not very well developed; core fractures with no preferred orientation

20: 256.0 m (840'); 64.2 l/t; dark brown microlaminated dolomitic marlstone; 75% of the sample displays continuous microlaminae; 25% of the sample is massive with no visible laminae; 66% of the continuous laminae are contorted; core fractures, approximating bedding, into 5 to 7 cm thick blocks

21: 283.2 m (929'); 74.6 l/t; 50% dark brown contorted microlaminated dolomitic marlstone; laminae are offset by microfaults; feathery discontinuous laminae within a granular dolomite matrix; fractures with some preferred orientation; 50% dark brown (medium brown on exposed surface) massive dolomitic marlstone; discontinuous organic microlaminae in a granular dolomite matrix; fractures with no preferred orientation

Canadian Occidental Petroleum Albert Mines 7

1: 32.0 m (105'); 45.9 l/t; shale, medium grey; silty with up to 11% quartz silt; in part, brownish; 10% dolomite content; siltstone laminae and interbeds to 0.3 cm; some dark brown to black organic detritus bedding planes; fairly laminated; generally hard, some fissility but not good cleavage; numerous slickensides on bedding planes; slickensides are brownish and seem to occur on organic laminae; 38° dip; discolouration and slight colour on heating suggest some organic content

2: 56.7 m (186'); 52.1 l/t; shale, medium grey to brownish-grey, slightly dolomitic; to a maximum of 10% dolomite content; some finely disseminated dark organic content, indeterminate as it is extremely fine; bedding not evident as zone is rubbled and has slickensides in all directions and on irregular surfaces; slickensides are brown; discolouration and odor on heating indicates some organic content; zone basically hard but portions break easily because of structural rubbling

3: 108.8 m (357'); 57.5 l/t; shale, medium greyish-brown, finely laminated; dark brown fine organic laminae; odor on breaking; scattered carbonaceous plant debris; hard; dolomitic, with some microcrystallinity evident at x50 power; some brownish-black slickensided surfaces; in part light weight and will give good thin edge that ignites, but mostly is too hard and nonfissile; some oil shale marlstone; 60° dip

4: 115.8 m (380'); 63.0 l/t; marlstone, medium greyish-brown to brown; microcrystalline texture, abundant carbonaceous (humic) debris; scattered fine quartz grains; odor on breaking; massive, hard; no good bedding evident but irregular banded colour mottling; dipping at 70°; hard to create thin edge but larger edges discolour on heating; slight odor; a few feldspar grains with quartz in some sandier lenses; only very slight dolomite reaction in acid

5: 158.8 m (521'); 11.3 l/t; shale, medium grey, laminated, subfissile; black grey slickensides, with zones of light grey, hard siliceous siltstone with considerable fine plant debris; 45° dip; not apparently an oil shale, but of interest for humic content

5A: 212.8 m (698'); 25.0 l/t; conglomerate; brown because of oil stain, heavily saturated; green to grey pebbles, some quartz; brown muddy matrix; poor, ineffective porosity; rock color is grey; no evidence of bedding; pale green to brown clay slickensides on one end of sample

6: 234.4 m (769'); 90.5 l/t; shale-marlstone, medium brownish-grey, very finely laminated to varved; hard, but splits in bedding planes, most of which are shiny slickensided, and

brownish coloured, has occasional calcite laminae along bedding plane; seems also to be slightly dolomitic; in part with very slight, very fine silt (quartz) content; appears to have some organic content but no plant material evident; smokes readily on heating

7: 357.8 m (1174'); 53.4 l/t; marlstone, brown-grey; scattered brown kerogen laminae to micro-bands of laminae; silty quartz zones and interbeds; probably less than 5% kerogen laminae and only minor kerogen flecks in massive marlstone; occasional carbonaceous fragments; very fine irregular wavy limestone; not varved; average 5° dip

8: 409.0 m (1342'); 12.5 l/t; conglomerate-grey; fragments to 1.3 cm of dominantly quartzose granitic (?) fragments in a grey to greenish-grey mud matrix; many quartz pebbles, some greenish coloured pebbles; brown slickensided matrix at one end of sample containing possible plan debris; some brownish patches of matrix may be oil stain; no bedding on dip

9: 442.3 m (1451'); 13.3 l/t; dolomite, light brown, argillaceous; contains, irregularly flecked kerogen along indistinct wavy bedding planes; some large sub-round elongate brown quartzitic (?) pebbles along general bedding zone; abundant grain to pebble size quartz fragments in half of the sample; brown organic slickensides at one end of core sample, other end has irregular breakage on brown massive dolomite marlstone; irregular, somewhat vague dip at 45°, approximately

AtlanticRichfield Boudreau 1

1: 132.9 m (436'); 3.8 l/t; shale, light grey, laminated but only very slightly; fissile, will break on bedding planes and on slickensided (medium to dark grey) bedding planes; occasional silty (quartz) laminae; 20° dip to core axis

2: 147.8 m (485'); 16.8 l/t; sandstone, brown, heavily oil stained, quartzose with some possible feldspar, in part calcareous, possible siliceous overgrowth; no apparent bedding; uniform grain size, massive; probable ineffective porosity; possible 15 to 20° dip to core axis

3: 195.1 m (640'); 17.1 l/t; marlstone, light grey to greyish-brown, in part grading to dolomitic shale; very fine carbonaceous (kerogen ?) flecks; a few brownish bands may have higher carbon content; fissile; laminated by the presence of thin bands light grey dolomitic argillaceous quartzose siltstone containing black carbonaceous flecks; occasional lime grades to very light grey very fine grained quartzose sandstone; dip 5° to core axis

4: 261.5 m (858'); 16.3 l/t; marlstone, light brownish-grey to greyish-brown; laminated to some very finely laminated; scattered to closely spaced kerogen laminae; silty throughout and grading to some bands of light grey dolomitic siltstone; possibly very fine flecks of carbonaceous debris; splits on laminae but only poorly, not fissile; dip 10° to core axis

5: 289.0 m (948'); 2.5 l/t; dolomite, light brown, massive, virtually no kerogen evident; traces at best of very finely disseminated quartz silt; occasional irregular blebs and patches containing quartz with siliceous overgrowth, void fillings which in part appear to be breccias; some possible very fine carbonaceous debris, some flat bedding evident by slight colour change related to variable silt-sand quartz content; dip 10° to core axis, probably argillaceous

6: 307.8 m (1010'); 44.2 l/t; marlstone, brown, laminated; laminae recognized by a number of continuous kerogen laminae and by variations in content of grey quartz, silt; no fissility; in part brecciated and contorted with a few thin quartz veinlets along contorted bedding plane brecciation; average dip ±20°

7: 315.2 m (1034'); 35.0 l/t; marlstone, brownish-grey to greyish-brown, indefinite brown kerogen laminae and flecks; silty to sandy, with light grey silstone to sandstone laminae and lenses; bedding best defined by silt variations and secondly by kerogen content

8: 371.9 m (1220'); 83.8 l/t; marlstone to sandstone, brown to grey-brown, laminated to varved; individual bands with

concentrated kerogen laminae; colour banding mostly by variations of sand content; massive sandy marlstone; some dark slickensided bedding planes; 10° dip to core axis

9: 375.8 m (1233'); 37.1 l/t; marlstone, sandy to marly sandstone, brownish-grey to greyish-brown, in part silty, fine lamination and hardly evident from variations of quartz content; only minor kerogen laminae or flecks; possible albertite and/or carbonaceous flecks and irregular fine debris; massive; hard; breaks on some bedding planes due to apparent clay content; fish teeth; 10° average dip to core axis

10: 379.2 m (1244'); 123.8 l/t; marlstone, greyish-brown, smooth to wavy finely laminated by regular to discontinuous kerogen laminae; variably silty to very fine grained sand in irregular beds to lenses and some regular laminae; somewhat contorted, poor breakage on bedding planes, sub-fissile, does not split easily; structurally disturbed, average dip 20° to core; possible shark teeth

11: 433.1 m (1431'); 96.3 l/t; marlstone, greyish-brown, finely laminated-banded; many good continuous wavy kerogen laminae; silty with some grey sand laminae to thin beds; most of laminae evident from kerogen but some by variations of quartz, silt-sand content; sedimentary cross-bedding; average dip about 30° to core

12: 443.2 m (1454'); 132.6 l/t; marlstone, greyish-brown, silty; distinct but somewhat faint lamination; structural contortion and some brecciation; patchy beds with abundant kerogen laminae separated by greyer siltier zones; some minor thrusting; dip averages about 30° from core

13: 475.5 m (1560'); 12.9 l/t; silty to sandy dolomite marlstone, brownish-grey; poorly laminated by greyish-brown laminae which could be kerogen clay; numerous thin interbeds of light grey fine grained sandstone; bedding at 5° to core; hard very irregular breakage parallel to bedding

14: 481.3 m (1579'); 56.7 l/t; marlstone, medium grey to brown, laminated; silty; some sandy lenses; scattered thin zones with definite brown laminae; hard; irregular breakage parallel to bedding; bedding somewhat contorted which seems to be depositional with some slump and scour infill; bedding 5° to core

15: 551.4 m (1809'); 115.1 l/t; marlstone, brownish-grey, silty and sandy; some very poor varving; numerous dip contortions, appears to be sedimentary slump and brecciation; drape around sandy patches; some sand lenses; average 20° dip to core, darker than most of samples (above); possibly a siltstone

AtlanticRichfield Dover 1A

1: 34.1 m (112'); 65.1 l/t; marlstone, medium greyish-brown generally massive appearing, but microscopically laminated with probable argillaceous content, in part grading to shale; in part silty; dark discontinuous organic kerogen blebs; scattered brown elongate dolomite spheres may infill ostracods; in part sub-fissile not generally chunky; approximate 15° dip

2: 40.9 m (134'); 15.8 l/t; shale, light grey, chunky to sub-laminated, very slightly dolomitic; possibly some thin marlstone laminae; 10° dip

3: 191.1 m (627'); 42.1 l/t; marlstone, greyish-brown, argillaceous, in part silty, in part grading to shale, greyish-brown dolomitic; chunky to some fairly fissile due to differing clay content; 10° dip

4: 198.7 m (652'); 15.0 l/t; shale, variably banded brown to grey with brown approaching dolomitic shale; some silty quartz zones (15 to 20% quartz); generally massive but some breakage on more argillaceous bands; contortions with calcite infill on fractures approximate bedding laminae; mostly argillaceous with little good marlstone although a few bands of good brown laminae may be mostly marlstone

5: 202.7 m (665'); 85.1 l/t; marlstone, brown, massive, hard, very finely laminated to almost varved; zones with abundant good continuous kerogen laminae; a few dark to black specks of possible carbonaceous debris, in part very slightly silty; 10° dip, quite uniform

Canadian Occidental Petroleum Rosevale 1

A: 310.9 m (1020'); 15.0 l/t; shale, medium brownish-grey, dolomitic (5%); scattered plant debris; fairly hard; generally finely laminated but only partially fissile; some good bedding plane fissility but some irregular breakage; one thin (0.3 cm) irregular nearly vertical pyrite filled fracture; uniform 10° dip

B: 314.6 m (1032'); 0.0 l/t; shale, medium grey; no carbonate content; traces of very fine carbonaceous (plant) debris; generally finely laminated but only irregular fissility on bedding planes; irregular breakage but more fissile than 1 above, which is much harder; uniform 10° dip

Note: The above two samples were selected to determine the meaning of the dolomitic versus non-dolomitic mineralogy and associated colour change relative to organic content.

1: 512.7 m (1682'); 20.9 l/t; shale, medium grey to brownish-grey; only slight brown tinge; non-dolomitic; silty with 10% very fine quartz grain silt; traces of very fine carbonaceous debris; very fine irregular wavy bedding; massive; breakage independent of bedding planes, scattered disseminated microcrystals of pyrite; average dip about 15°; minor muscovite; brown slickensided surfaces on bedding planes

2: 598.0 m (1962'); 21.7 l/t; sandstone, brown (due to oil stain), depositionally grey; very fine grained quartz; probably feldspar also but identification difficult because of oil stain; siliceous cement; hard, massive; no effective porosity; slight odor on breaking; scattered fine pyrite crystals; no evidence of carbonaceous debris; sample taken to determine if oil stain is related to the oil shale zone

3: 603.8 m (1981'); 17.9 l/t; shale, dark grey, very slight brownish tinge; very hard; fine mottled irregular wavy laminae; not fissile nor breakable on laminae except sporadically; possibly 2% dolomite content; 15° average dip

4: 612.6 m (2010'); 53.4 l/t; shale, dark grey with very fine dark greyish-brown laminae of apparent organic debris; 10% dolomite content; variably 5 to 10% quartz silt to fine grained sand; very finely laminated but hard; breakage occurs along the laminae; scattered, very fine ptygmatic micro-folds along bedding in zones with maximum organic laminae; 5° average dip

5: 632.5 m (2075'); 21.3 l/t; shale, dark grey; no brownish tinge; non-dolomitic to traces, at the most; 10 to 15% very fine quartz silt; very finely laminated due to silt content; no evidence of significant brown organic laminae;

hard, but splits in laminae; 2.5 cm band of coarse quartz clastics detritus with irregular elongate albertite blebs; some variations to bedding, with dip averaging about 4°

6: 635.8 m (2086'); 50.5 l/t; shale, dark grey; very slightly dolomitic at best (2%); 10 to 15% very fine quartz silt, very fine wavy laminae, in part showing some cross-bedding and discontinuity of lamination; breaks poorly along the laminae; very hard; some black carbonaceous debris along laminae; in part appears to be of humic (plant) origin although some appears to be albertite; does not appear to be a good oil shale zone

AtlanticRichfield Urney 1

1: 71.9 m (236'); 7.5 l/t; marlstone, brown massive to brown laminated dolomite, very silty with quartz to 40% and some siltstone laminae to thin beds; in part almost varved with dark laminae which appear grey to brown and may be clay or kerogen; uniform bedding dip at 25° to core axis

2: 94.2 m (309'); 7.9 l/t; marlstone, brown to grey, hard, very silty with quartz to 40% and silt laminae and lenses; minor brown kerogen laminae impart distinct bedding appearance, also evident from silt variations; hard, may be closer to siltstone rather than marlstone; 30° uniform dip to core axis

3: 106.7 m (350'); 12.1 l/t; marlstone, brown to greyish-brown; finely laminated to almost varved; in part silty in grains and laminae, less than 10% quartz silt; contorted bedding with microfolds and faults, averaging 50° dip to core, some slickensided zones

4: 228.9 m (751'); 33.8 l/t; marlstone, medium brownish-grey to brown; finely laminated to almost varved, numerous dark grey quartz, silt laminae; dip about 70° to 80° to core axis

APPENDIX 3

X-RAY DIFFRACTION RESULTS

No.	Depth (m)	Zone	Dol %	Cal %	Qtz %	Fspar %	Il %	MLC %	Ch/K %	Sid %	Py %	Anal %	Other %
AtlanticRichfield Albert Mines 1A													
1	240.8	CM	10	-	57	12	9	6	-	6	-	-	-
2	249.6	CM	26	-	34	16	4	7	-	6	1	-	βQtz:6
3	292.0	DM	33	-	37	17	tr	8	-	3	2	-	βQtz:tr/Apa
4	305.1	DM	16	-	47	21	4	6	-	5	1	-	-
Canadian Occidental Petroleum Albert Mines 2													
1	20.4	US	tr	13	57	6	tr	15	4	3	2	-	Apa
2	44.8	US	9	17	44	8	9	10	-	-	3	-	-
3	69.2	US	2	10	61	10	5	8	2	-	2	-	-
4	89.9	AM	4	15	50	14	6	8	tr	2	1	-	Apa
5	107.9	AM	9	10	47	20	4	7	-	2	1	-	Apa
5A	110.9	AM	66	5	29	tr	-	tr	-	-	-	-	-
6	125.0	AM	5	26	38	9	6	12	tr	2	2	-	-
6A	128.6	AM	15	6	52	8	10	9	-	tr	-	-	-
7	140.8	AM	21	36	34	6	tr	tr	-	tr	3	-	-
8	166.4	AM	8	13	45	9	5	9	3	4	2	-	βQtz:2/Apa
9	178.6	AM	9	14	42	9	tr	15	-	2	3	-	βQtz:6
9A	238.0	CM	16	-	52	7	5	13	-	7	-	-	-
10	241.1	DM	11	-	55	13	6	9	-	3	3	-	βQtz:4/Apa
11	244.4	DM	18	-	45	8	10	8	-	7	-	-	-
Canadian Occidental Petroleum Albert Mines 4													
1	415.1	US	9	15	49	7	6	8	tr	3	3	-	-
2	431.0	AM	12	5	41	14	8	12	-	5	3	-	-
3	431.9	AM	11	8	36	12	11	13	-	3	6	-	-
4	445.9	AM	44	tr	47	9	-	tr	-	tr	tr	-	-
5	450.8	AM	13	13	33	19	1	10	tr	2	tr	-	-
6	456.3	AM	11	7	53	7	8	11	-	-	3	-	-
7	465.4	AM	20	7	45	14	4	7	-	2	1	-	-
8	474.9	AM	15	-	61	10	5	8	-	tr	-	-	-
9	476.4	AM	17	10	36	7	9	11	-	tr	3	-	βQtz:7
10	484.6	AM	9	20	39	12	7	7	-	3	tr	-	Apa:tr
11	495.6	AM	12	9	51	10	7	8	-	-	3	-	-
12	502.3	AM	66	-	23	11	-	tr	-	tr	tr	-	-
13	517.6	CM	12	-	50	7	12	11	-	8	-	-	-
Canadian Occidental Petroleum Albert Mines 5													
1	78.0	US	6	-	57	13	9	12	tr	3	-	-	-
2	142.6	US	54	-	38	8	tr	tr	-	-	-	-	-
3	146.3	US	65	-	35	-	-	tr	-	-	-	-	-
4	172.2	US	12	22	46	5	11	tr	-	tr	4	-	-
5	181.4	US	42	-	38	5	3	10	tr	-	2	-	-

No.	Depth (m)	Zone	Dol %	Cal %	Qtz %	Fspar %	Il %	MLC %	Ch/K %	Sid %	Py %	Anal %	Other %
6	192.3	US	11	11	49	7	7	13	tr	tr	2	-	-
7	197.8	AM	19	9	41	13	8	10	-	-	tr	-	Amph:tr
8	202.1	AM	2	41	35	9	4	7	-	-	2	-	-
9	208.2	AM	20	4	34	8	11	10	-	-	6	-	Amph:tr
10	233.2	AM	5	10	49	15	10	8	-	-	3	-	-
11	238.4	AM	3	55	24	4	6	6	-	tr	2	-	-
12	253.0	AM	8	8	49	11	8	14	-	tr	2	-	-
13	256.6	AM	9	17	49	10	5	7	-	1	2	-	-
14	267.0	AM	10	26	39	9	6	6	-	2	2	-	-
15	268.8	AM	4	8	65	11	4	5	-	tr	3	-	-
16	279.5	AM	6	20	50	8	6	8	-	2	-	-	-
17	282.5	AM	4	33	46	7	tr	7	-	2	1	-	-
18	285.9	AM	10	24	41	7	5	7	-	2	-	-	βQtz:4
19	345.9	CM	25	-	47	17	tr	5	-	2	2	-	Apa:2
20	363.9	CM	12	-	60	10	6	8	-	tr	2	-	Apa:2
21	399.9	DM	46	4	20	10	4	4	-	3	-	-	βQtz:9
22	414.5	DM	16	-	36	22	5	7	-	7	-	-	βQtz:7
23	447.1	DM	39	tr	24	18	tr	11	-	-	4	-	βQtz:4/Apa:tr
24	487.7	DM	35	-	21	22	5	7	-	-	-	-	βQtz:5
25	504.1	DM	29	-	6	37	7	11	-	10	-	-	-
26	535.2	DM	22	-	28	32	4	5	-	9	-	-	-
27	591.6	DM	17	-	18	53	tr	tr	-	8	-	-	βQtz:4
28	598.0	DM	43	-	13	44	-	tr	-	-	-	-	-
29	606.6	DM	45	-	19	31	tr	tr	-	5	-	-	-
30	652.3	DM	19	-	16	42	4	7	-	-	4	-	βQtz:3
31	656.8	DM	32	-	17	41	-	tr	-	5	5	-	-
32	664.5	DM	25	-	7	43	6	5	-	10	4	-	Gyp:tr
33	710.2	DM	6	3	45	13	11	tr	-	13	-	-	βQtz:9
34	737.6	DM	29	-	29	38	tr	tr	-	-	1	-	Apa:3
35	743.7	DM	24	-	23	28	8	8	-	9	-	-	-
Canadian Occidental Petroleum Albert Mines 6													
1	68.6	CM	25	-	43	6	9	8	-	5	-	-	βQtz:4
2	77.1	CM	27	-	50	10	3	5	tr	3	tr	-	Gyp:2
3	81.7	CM	41	-	37	6	-	10	-	6	-	-	Apa
4	91.5	CM	7	-	63	10	7	10	-	3	tr	-	Apa
5	103.6	CM	11	-	39	13	9	13	-	5	3	-	βQtz:7/Apa
6	121.9	DM	28	-	26	11	8	7	-	8	tr	-	βQtz:12
7	132.0	DM	4	-	35	31	5	8	-	8	2	-	βQtz:7
8	143.6	DM	30	-	26	25	tr	9	-	3	2	-	βQtz:5
9	153.3	DM	9	-	33	15	11	10	-	12	tr	-	βQtz:10
10	182.3	DM	22	-	19	29	6	6	-	14	-	-	βQtz:4
11	185.3	DM	30	-	6	45	tr	tr	-	10	3	-	βQtz:6
12	188.1	DM	26	-	14	35	4	6	-	15	-	-	-
13	194.8	DM	41	-	16	31	tr	9	-	3	-	-	-
14	199.3	DM	15	-	23	50	tr	tr	-	2	5	-	βQtz:5
15	204.2	DM	21	-	6	54	4	4	-	7	4	-	-
16	214.9	DM	39	-	25	29	tr	tr	-	7	-	-	-

No.	Depth (m)	Zone	Dol %	Cal %	Qtz %	Fspar %	Il %	MLC %	Ch/K %	Sid %	Py %	Anal %	Other %
17	237.7	DM	22	-	24	37	tr	8	-	6	-	-	βQtz:3
18	242.0	DM	41	-	21	5	-	tr	-	3	tr	-	Apa
19	246.9	DM	40	-	25	20	5	7	-	3	-	-	Apa
20	256.0	DM	41	-	8	35	-	tr	-	8	-	-	Apa:8
21	283.2	DM	17	-	9	61	tr	tr	-	7	6	-	-
Canadian Occidental Petroleum Albert Mines 7													
1	32.0	HB	58	-	19	17	tr	6	tr	tr	-	-	-
2	56.7	HB	11	-	40	29	7	8	5	-	-	-	-
3	108.8	AM	15	-	45	27	8	tr	5	-	tr	-	-
4	115.8	AM	13	-	47	33	3	2	-	-	2	-	-
5	158.8	DS	-	16	25	6	6	8	7	-	-	32	-
5A	212.8	RH	8	-	49	27	4	4	4	-	-	-	-
6	234.4	RH	4	36	25	17	tr	9	4	-	5	-	-
7	357.8	DS	12	7	40	26	4	4	3	2	2	-	Apa
8	409.0	RH	11	-	50	19	3	5	4	tr	5	-	-
9	442.3	RH	34	-	38	10	6	10	tr	-	-	-	βQtz:2
AtlanticRichfield Boudreau 1													
1	132.9	HB	-	13	57	13	10	tr	7	-	-	-	-
2	147.8	HB	-	23	43	32	tr	tr	tr	-	2	-	-
3	195.1	US	7	23	44	9	5	tr	tr	-	-	12	-
4	261.5	US	7	-	31	14	6	9	7	-	3	23	-
5	289.0	US	25	tr	21	6	6	9	4	-	-	29	-
6	302.8	AM	28	-	28	9	10	7	tr	tr	3	15	-
7	315.2	AM	41	-	27	25	tr	5	-	-	2	-	-
8	371.9	AM	23	-	45	32	tr	tr	-	-	-	-	-
9	375.8	AM	6	35	23	10	7	16	-	3	tr	-	-
10	379.2	AM	15	5	35	25	5	8	3	2	2	-	-
11	433.1	DM	7	9	39	22	6	12	-	3	2	-	-
12	443.2	DM	14	32	27	13	7	7	tr	-	tr	-	-
13	475.5	DM	54	tr	20	26	tr	tr	-	tr	tr	-	-
14	481.3	DM	8	tr	47	23	9	tr	-	5	2	-	βQtz:6
15	551.4	RH	32	tr	21	31	tr	10	-	6	-	-	-
AtlanticRichfield Dover 1A													
1	34.1	US	18	-	40	9	7	9	5	-	12	-	Amph:6
2	40.9	US	-	11	54	6	6	11	3	6	3	-	-
3	191.1	DM	32	tr	36	8	10	7	5	2	-	-	Amph:6
4	198.7	DM	tr	27	39	9	10	9	6	-	-	-	-
5	202.7	DM	26	5	40	14	4	6	tr	-	5	-	-
Canadian Occidential Petroleum Rosevale 1													
A	310.9	HB	24	-	70	8	6	4	-	-	-	13	-
B	314.6	HB	9	tr	17	8	12	7	8	-	4	35	-
1	512.7	HB	-	tr	46	6	10	8	tr	-	-	30	-
2	598.0	US	17	-	63	20	tr	tr	-	-	-	-	-
3	603.8	US	48	-	17	20	-	tr	-	-	3	12	-

No.	Depth (m)	Zone	Dol %	Cal %	Qtz %	Fspar %	Il %	MLC %	Ch/K %	Sid %	Py %	Anal %	Other %
4	612.6	AM	50	-	15	32	-	tr	-	-	3	-	βQtz:tr
5	632.5	CM	26	-	tr	10	-	tr	-	4	4	56	-
6	635.8	CM	33	-	26	28	6	7	-	-	-	-	-
AtlanticRichfield Urney 1													
1	71.9	AM	49	-	21	30	tr	-	-	-	-	-	-
2	94.2	AM	27	-	23	34	4	8	-	4	-	-	-
3	106.7	AM	30	6	32	23	tr	9	tr	-	-	-	-
4	228.9	DM	84	9	4	3	-	tr	tr	tr	-	-	-

Canadian Occidental Petroleum Albert Mines 2 (surface weathering product)

127.1 Rozenite - 68%; Gypsum - 9%; Quartz - 7%; βQuartz - 12%; Pyrite - 4%

Abbreviations:

Dol	- Dolomite
Cal	- Calcite
Qtz	- Quartz
Fspar	- Feldspar
Il	- Illite
MLC	- Mixed Layer Clays
Ch/K	- Chlorite and/or Koolinite
Sid	- Siderite
Py	- Pyrite
Anal	- Analcime
Amph	- Amphibole
Apa	- Apatite
Gyp	- Gypsum
tr	- trace

APPENDIX 4A

FISCHER ASSAY RESULTS

No.	Depth (m)	Zone	Bulk Density (gm/cc)	Yield (l/t)	Water (Wt.%)	Oil Gravity (gm/cc)	Organic Carbon (Wt.%)	Total Carbon (Wt.%)
AtlanticRichfield Albert Mines 1A								
1	240.8	CM	2.12	78.0	1.8	0.913	8.14	10.28
2	249.6	CM	1.92	79.6	1.5	0.913	5.54	8.26
3	292.0	DM	2.19	65.9	0.8	0.911	8.00	11.16
4	305.1	DM	1.79	56.7	0.5	0.909	8.07	10.87
Canadian Occidental Petroleum Albert Mines 2								
1	20.4	US	2.07	97.2	2.2	0.869	9.84	11.48
2	44.8	US	2.01	28.4	1.6	0.870	3.71	7.76
3	69.2	US	2.19	65.5	2.2	0.876	6.83	8.25
4	89.9	AM	2.19	148.9	1.4	0.874	15.68	18.41
5	107.9	AM	2.11	93.0	1.4	0.870	7.14	9.74
5A	110.9	AM	2.34	44.2	1.1	0.870	2.71	11.66
6	125.0	AM	1.81	118.8	1.5	0.878	13.61	17.57
6A	128.6	AM	1.93	100.1	1.8	0.878	8.96	11.56
7	140.8	AM	1.99	65.1	0.7	0.879	6.03	12.77
8	166.4	AM	1.67	162.2	1.2	0.876	12.27	15.23
9	178.6	AM	1.89	140.5	1.1	0.878	8.24	11.27
9A	238.0	CM	*	38.8	3.5	0.877	2.46	4.98
10	241.1	DM	2.07	100.9	1.6	0.880	10.66	12.87
11	244.4	DM	2.37	50.5	2.4	0.877	4.07	6.92
Canadian Occidental Petroleum Albert Mines 4								
1	415.1	US	2.39	27.9	2.6	0.858	4.10	6.50
2	431.0	AM	2.18	126.8	1.7	0.870	8.35	10.33
3	431.9	AM	1.95	142.6	1.6	0.879	12.46	14.42
4	445.9	AM	2.61	22.5	0.5	0.877	5.12	11.38
5	450.8	AM	2.03	134.7	0.9	0.880	11.98	15.06
6	456.3	AM	2.28	65.5	1.9	0.879	7.25	9.06
7	465.4	AM	2.31	59.2	1.5	0.879	7.94	10.72
8	474.9	AM	2.26	102.2	1.0	0.877	10.27	13.20
9	476.4	AM	2.23	82.6	1.1	0.874	19.64	21.90
10	484.6	AM	2.10	108.0	0.8	0.878	12.20	15.21
11	495.6	AM	2.45	33.4	1.7	0.877	3.70	6.06
12	502.3	AM	2.27	57.1	1.0	0.876	1.91	11.08
13	517.6	CM	*	20.4	4.0	0.875	1.91	3.72
Canadian Occidental Petroleum Albert Mines 5								
1	78.0	US	1.88	155.5	1.4	0.875	17.14	18.35
2	142.6	US	2.34	59.6	1.7	0.876	3.82	10.00
3	146.3	US	2.68	23.8	0.8	0.872	0.96	10.25
4	172.2	US	2.44	37.1	1.2	0.874	5.47	9.32
5	181.4	US	2.59	36.3	1.4	0.875	2.96	10.25

No.	Depth (m)	Zone	Bulk Density (gm/cc)	Yield (l/t)	Water (Wt.%)	Oil Gravity (gm/cc)	Organic Carbon (Wt.%)	Total Carbon (Wt.%)
6	192.3	US	1.87	83.8	1.5	0.878	7.61	10.35
7	197.8	AM	2.07	123.4	1.3	0.877	10.81	14.97
8	202.1	AM	2.11	105.1	1.5	0.876	10.50	14.03
9	208.2	AM	1.85	132.6	2.1	0.880	11.37	13.41
10	233.2	AM	1.83	115.5	1.8	0.878	13.17	14.54
11	238.4	AM	1.99	83.0	1.6	0.882	11.30	14.14
12	253.0	AM	1.70	167.2	1.6	0.880	22.41	24.39
13	256.6	AM	2.06	148.9	1.2	0.883	15.33	18.13
14	267.0	AM	1.82	102.2	0.9	0.887	15.77	19.37
15	268.8	AM	1.35	262.7	1.8	0.890	29.31	31.16
16	279.5	AM	1.89	111.3	1.1	0.890	8.26	10.47
17	282.5	AM	1.98	60.5	1.0	0.892	7.10	11.17
18	285.9	AM	2.35	50.5	1.2	0.891	4.54	8.63
19	345.9	CM	2.19	84.7	1.2	0.893	9.17	12.58
20	363.9	CM	1.97	90.1	0.9	0.888	9.76	11.52
21	399.9	DM	2.13	28.8	0.4	0.892	2.24	8.02
22	414.5	DM	2.04	75.9	0.4	0.890	8.25	11.56
23	447.1	DM	2.19	72.6	0.5	0.894	7.80	12.85
24	487.7	DM	2.40	33.4	0.2	0.892	3.78	7.48
25	504.1	DM	2.24	88.0	0.2	0.893	9.16	12.45
26	535.2	DM	2.38	44.6	0.2	0.889	4.21	7.47
27	591.6	DM	2.08	43.8	0.4	0.894	4.95	8.15
28	598.0	DM	2.07	85.5	0.5	0.889	14.57	18.90
29	606.6	DM	2.35	22.9	0.3	0.895	2.93	7.43
30	652.3	DM	2.06	72.6	0.3	0.899	9.23	12.09
31	656.8	DM	2.16	53.6	0.3	0.889	6.50	9.93
32	664.5	DM	2.40	31.7	0.4	0.880	4.61	6.93
33	710.2	DM	2.50	70.4	0.7	0.871	2.48	4.18
34	737.6	DM	2.02	69.4	0.3	0.871	6.90	10.36
35	743.7	DM	2.22	26.3	0.2	0.869	2.44	5.73
Canadian Occidental Petroleum Albert Mines 6								
1	68.6	CM	2.01	47.5	1.4	0.869	5.00	7.99
2	77.1	CM	2.02	49.6	2.5	0.922	4.97	7.75
3	81.7	CM	2.17	35.4	2.2	0.920	3.74	8.55
4	91.5	CM	2.12	71.7	2.2	0.919	8.93	9.83
5	103.6	CM	2.28	91.3	1.4	0.921	10.52	12.16
6	121.9	DM	2.23	65.9	0.4	0.919	8.67	12.01
7	132.0	DM	2.14	111.8	0.5	0.918	13.33	14.80
8	143.6	DM	2.12	96.7	0.5	0.919	11.71	15.24
9	153.3	DM	2.37	48.8	0.9	0.913	5.45	7.57
10	182.3	DM	2.37	58.8	0.3	0.914	5.86	9.91
11	185.3	DM	2.24	62.6	0.3	0.904	6.96	10.31
12	188.1	DM	2.29	61.7	0.4	0.904	5.37	9.73
13	194.8	DM	2.43	33.8	0.2	0.899	3.93	8.03
14	199.3	DM	2.14	62.1	0.6	0.901	8.95	11.69
15	204.2	DM	1.89	157.2	0.5	0.903	17.00	19.40
16	214.9	DM	2.43	43.8	0.2	0.904	6.24	10.70

No.	Depth (m)	Zone	Bulk Density (gm/cc)	Yield (l/t)	Water (Wt.%)	Oil Gravity (gm/cc)	Organic Carbon (Wt.%)	Total Carbon (Wt.%)
17	237.7	DM	2.53	55.5	0.4	0.899	6.07	8.92
18	242.0	DM	1.22	193.9	0.6	0.897	22.12	26.00
19	246.9	DM	2.49	28.8	0.2	0.895	3.16	7.01
20	256.0	DM	2.26	64.2	0.4	0.899	10.47	14.27
21	283.2	DM	2.15	74.6	0.4	0.901	11.26	13.18
Canadian Occidental Petroleum Albert Mines 7								
1	32.0	HB	2.38	45.9	0.7	0.891	3.52	9.77
2	56.7	HB	2.28	52.1	0.7	0.897	5.77	7.49
3	108.8	AM	2.35	57.5	0.4	0.891	5.53	7.41
4	115.8	AM	2.31	63.0	0.2	0.887	5.56	7.97
5	158.8	DS	2.44	11.3	2.1	0.889	1.62	3.23
5A	212.8	RH	2.43	25.0	0.4	0.887	1.80	3.28
6	334.4	RH	2.12	90.5	0.5	0.884	10.31	13.44
7	357.8	DS	2.36	53.4	0.4	0.884	8.14	10.38
8	409.0	RH	2.54	12.5	0.4	0.879	3.20	5.23
9	442.3	RH	2.54	13.3	0.2	0.888	2.11	5.42
AtlanticRichfield Boudreau 1								
1	132.9	HB	2.59	3.8	1.4	0.914	0.56	1.68
2	147.8	HB	2.25	16.8	0.2	0.908	1.57	3.76
3	195.1	US	2.52	17.1	1.6	0.914	1.19	3.85
4	261.5	US	2.52	16.3	1.7	0.909	2.30	2.87
5	289.0	US	2.56	2.5	2.1	0.914	1.24	3.53
6	302.8	AM	2.59	44.2	0.9	0.917	4.49	7.20
7	315.2	AM	2.55	35.0	0.4	0.914	5.03	9.20
8	371.9	AM	2.25	83.8	0.6	0.916	9.52	12.57
9	375.8	AM	2.39	37.1	1.0	0.920	5.25	9.10
10	379.2	AM	2.05	123.8	0.7	0.918	15.31	18.10
11	433.1	DM	2.14	96.3	0.8	0.917	9.72	11.85
12	443.2	DM	2.09	132.6	0.9	0.918	13.99	18.86
13	475.5	DM	2.65	12.9	0.1	0.921	1.97	6.23
14	481.3	DM	2.29	56.7	0.5	0.914	10.88	12.43
15	551.4	RH	1.95	115.1	0.5	0.912	12.65	15.52
AtlanticRichfield Dover 1A								
1	34.1	US	2.26	65.1	1.8	0.908	15.24	17.54
2	40.9	US	2.48	15.8	3.1	0.909	2.36	3.41
3	191.1	DM	2.28	42.1	2.0	0.910	5.56	9.74
4	198.7	DM	2.51	15.0	1.6	0.909	2.04	5.96
5	202.7	DM	2.26	85.1	1.3	0.906	11.09	14.73
Canadian Occidental Petroleum Rosevale 1								
A	310.9	HB	2.24	15.0	1.3	0.889	2.15	4.58
B	314.6	HB	*	0.0	3.2	0.909	1.62	2.06
1	512.7	HB	2.47	20.9	0.8	0.889	1.21	1.44
2	598.0	US	2.47	21.7	0.2	0.891	1.95	4.34
3	603.8	US	2.57	17.9	0.8	0.887	3.40	7.81

No.	Depth (m)	Zone	Bulk Density (gm/cc)	Yield (l/t)	Water (Wt.%)	Oil Gravity (gm/cc)	Organic Carbon (Wt.%)	Total Carbon (Wt.%)
4	612.6	AM	2.43	53.4	0.2	0.884	5.53	10.64
5	632.5	CM	2.43	21.3	2.3	0.884	3.57	6.04
6	635.8	CM	2.53	50.5	0.5	0.889	6.30	9.84
AtlanticRichfield Urney 1								
1	71.9	AM	2.29	7.5	0.4	0.906	1.88	6.18
2	99.2	AM	2.24	7.9	0.1	0.906	2.36	5.18
3	106.7	AM	2.28	12.1	0.5	0.906	2.50	6.03
4	228.9	DM	2.40	33.8	0.4	0.898	0.93	11.95

* unsuitable for analysis

APPENDIX 4B

ROCK-EVAL PYROLYSIS RESULTS

No.	Depth	Zone	Organic Carbon (Wt.%)	S1 (mg/gm)	S2 (mg/gm)	S3 (mg/gm)	H Index	O Index	Oil/Gas Poten. (S1+S2)	Prod. Index $\left(\frac{S1}{S1+S2}\right)$	Tmax (°C)
AtlanticRichfield Albert Mines 1A											
1	240.8	CM	8.57	11.39	74.29	0.39	866.9	4.6	85.68	0.13	445
2	249.6	CM	7.97	10.88	77.46	0.34	971.9	4.3	88.34	0.12	445
3	292.0	DM	6.57	8.20	64.16	0.31	976.6	4.7	72.36	0.11	446
4	305.1	DM	5.77	8.59	51.28	0.24	888.7	4.2	59.87	0.14	440
Canadian Occidental Petroleum Albert Mines 2											
1	20.4	US	8.76	8.67	85.94	0.41	981.1	4.7	94.61	0.09	444
2	44.8	US	2.93	4.31	21.97	0.23	749.8	7.8	26.28	0.16	440
3	69.2	US	5.62	10.84	54.45	0.21	968.9	3.7	65.29	0.17	441
4	89.9	AM	12.06	12.82	118.68	0.25	984.1	2.1	131.50	0.10	446
5	107.9	AM	8.40	9.76	82.62	0.21	983.6	2.5	92.38	0.11	439
5A	110.9	AM	4.39	5.23	42.05	0.18	957.9	4.1	47.28	0.11	443
6	125.0	AM	10.64	10.79	105.36	0.31	990.2	2.9	116.15	0.09	450
6A	128.6	AM	8.73	12.84	87.13	0.29	998.1	3.3	99.97	0.13	445
7	140.8	AM	5.53	7.49	54.15	0.20	979.2	3.6	61.64	0.12	447
8	166.4	AM	12.23	11.04	105.78	0.47	864.9	3.8	116.82	0.09	452
9	178.6	AM	11.72	13.12	115.34	0.32	984.1	2.7	128.46	0.10	443
9A	238.0	CM	3.16	7.00	18.60	0.44	588.6	13.9	25.60	0.27	441
10	241.1	DM	8.55	12.38	83.55	0.33	977.2	3.9	95.93	0.13	443
11	244.4	DM	3.10	4.58	27.78	0.72	896.1	10.3	32.36	0.14	441
Canadian Occidental Petroleum Albert Mines 4											
1	415.1	US	2.95	3.85	14.86	0.44	503.7	14.9	18.71	0.21	440
2	431.0	AM	11.90	7.34	101.38	0.45	851.9	3.8	108.72	0.07	445
3	431.9	AM	12.35	8.54	118.39	0.32	958.6	2.6	126.93	0.07	445
4	445.9	AM	1.96	2.40	17.44	0.35	889.8	17.9	19.84	0.12	442
5	450.8	AM	11.91	5.44	99.27	0.36	833.5	3.0	104.71	0.05	450
6	456.3	AM	6.09	5.98	58.57	0.36	961.7	5.9	64.55	0.09	446
7	465.4	AM	6.46	5.96	60.65	0.27	938.9	4.2	66.61	0.09	451
8	474.9	AM	8.53	6.27	54.58	0.31	639.9	3.6	60.85	0.10	450
9	476.4	AM	9.88	4.66	81.97	0.32	829.7	3.2	86.63	0.05	448
10	484.6	AM	9.33	5.61	92.31	0.35	989.4	3.8	97.92	0.06	449
11	495.6	AM	3.68	3.56	33.08	0.38	898.9	10.3	36.64	0.10	442
12	502.3	AM	8.14	5.45	67.58	0.42	830.2	5.2	73.03	0.07	450
13	517.6	CM	2.21	2.99	10.76	0.47	486.9	21.3	13.75	0.22	442
Canadian Occidental Petroleum Albert Mines 5											
1	78.0	US	15.76	13.82	118.43	0.41	751.5	2.6	132.25	0.10	447
2	142.6	US	6.23	7.83	49.82	0.37	799.7	5.9	57.65	0.14	440
3	146.3	US	1.37	3.12	12.14	0.33	886.1	24.1	15.26	0.20	442
4	172.2	US	4.20	4.52	34.45	0.45	820.2	10.0	38.97	0.12	447
5	181.4	US	3.56	5.43	31.26	0.32	878.1	9.0	36.69	0.15	443

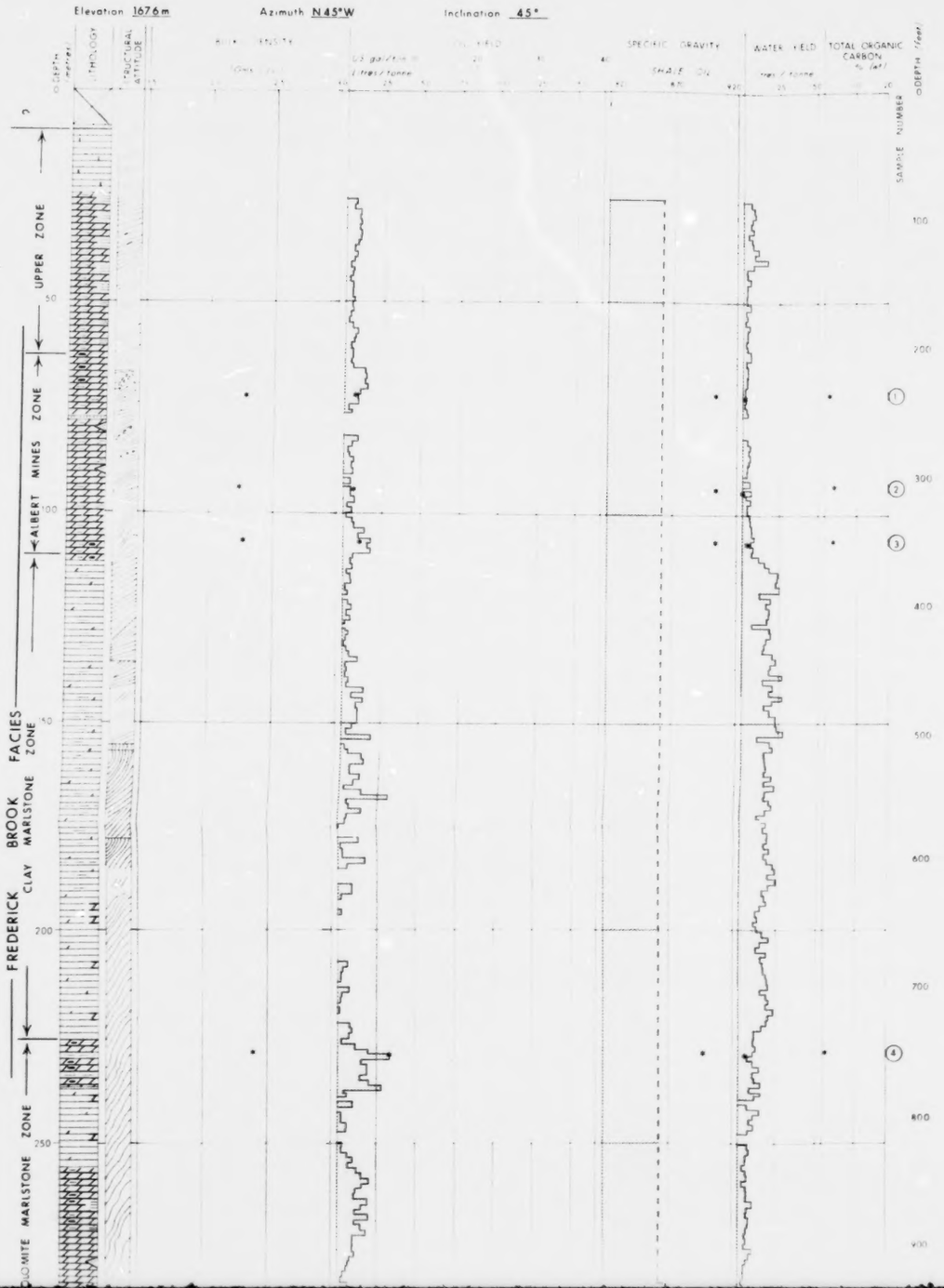
No.	Depth (m)	Zone	Organic Carbon (Wt.%)	S1	S2	S3 (mg/gm)	H Index	O Index	Oil/Gas Poten. (S1+S2)	Prod. Index (S1/(S1+S2))	Tmax (°C)
6	192.3	US	8.04	9.61	69.05	0.35	858.8	4.4	78.66	0.12	449
7	197.8	AM	11.18	11.94	98.65	0.35	882.4	3.1	110.59	0.11	448
8	202.1	AM	9.50	11.67	82.19	0.36	865.2	3.8	93.86	0.12	446
9	208.2	AM	14.33	14.71	116.19	0.39	810.8	2.7	130.90	0.11	448
10	233.2	AM	11.29	13.32	81.43	0.29	721.3	2.6	94.75	0.14	447
11	238.4	AM	6.83	11.09	65.99	0.21	966.2	3.1	77.08	0.14	450
12	253.0	AM	19.72	12.87	146.05	0.34	740.6	1.7	158.92	0.08	448
13	256.6	AM	16.44	10.96	118.03	0.27	717.9	1.6	128.99	0.08	450
14	267.0	AM	12.14	9.68	94.07	0.19	774.9	1.6	103.75	0.09	449
15	268.8	AM	24.69	13.97	157.19	0.23	636.7	0.9	171.16	0.08	445
16	279.5	AM	9.28	9.09	79.55	0.43	857.2	4.6	88.64	0.10	451
17	282.5	AM	5.22	6.46	47.33	0.25	906.7	4.8	53.79	0.12	445
18	285.9	AM	3.93	6.48	34.15	0.21	869.0	5.3	40.63	0.16	444
19	345.9	CM	8.46	10.15	66.09	0.43	781.2	5.1	76.24	0.13	447
20	363.9	CM	8.59	11.14	65.49	0.34	762.4	4.0	76.63	0.15	446
21	399.9	DM	2.07	7.38	18.33	0.21	885.5	10.1	25.71	0.29	436
22	414.5	DM	7.37	10.50	60.01	0.48	814.2	6.5	70.51	0.15	446
23	447.1	DM	5.99	11.45	56.04	0.50	935.6	8.3	67.49	0.17	443
24	487.7	DM	2.45	8.33	19.63	0.21	801.2	8.6	27.96	0.30	439
25	504.1	DM	7.77	13.57	75.27	0.39	968.7	5.0	88.84	0.15	444
26	535.2	DM	3.27	9.62	32.27	0.21	986.9	6.4	41.89	0.23	440
27	591.6	DM	4.34	10.39	31.61	0.26	728.3	6.0	42.00	0.25	440
28	598.0	DM	8.66	11.77	74.49	0.40	860.2	4.6	86.26	0.14	444
29	606.6	DM	2.09	7.20	15.97	0.22	764.1	10.5	23.17	0.31	436
30	652.3	DM	7.71	8.78	59.62	0.26	773.3	3.4	68.40	0.13	446
31	656.8	DM	5.87	8.73	46.35	0.16	789.6	2.7	55.08	0.16	448
32	664.5	DM	2.90	9.02	21.77	0.18	750.7	6.2	30.79	0.29	435
33	710.2	DM	2.03	7.11	11.77	0.20	579.8	9.9	18.88	0.38	433
34	737.6	DM	8.04	8.40	59.07	0.13	734.7	1.6	67.47	0.12	447
35	743.7	DM	2.37	8.73	16.82	0.21	709.7	8.9	25.55	0.34	432
Canadian Occidental Petroleum Albert Mines 6											
1	68.6	CM	4.96	6.10	37.50	0.30	756.0	6.0	43.60	0.14	444
2	77.1	CM	4.72	9.70	38.30	0.24	811.4	5.1	48.00	0.20	438
3	81.7	CM	3.03	3.90	27.17	0.36	896.7	11.9	31.07	0.13	440
4	91.5	CM	6.67	10.67	65.94	0.32	988.6	4.8	76.61	0.14	443
5	103.6	CM	10.81	12.93	81.72	0.24	756.0	2.2	94.65	0.14	440
6	121.9	DM	5.21	9.45	50.79	0.17	974.9	3.3	60.24	0.16	442
7	132.0	DM	11.02	11.87	84.47	0.16	766.5	1.5	96.34	0.12	444
8	143.6	DM	10.02	11.60	79.92	0.15	797.6	1.5	91.52	0.13	441
9	153.3	DM	4.25	8.63	38.27	0.12	900.5	2.8	46.90	0.18	443
10	182.3	DM	5.31	9.86	44.75	0.19	842.7	3.6	54.61	0.18	438
11	185.3	DM	5.47	15.21	47.28	0.20	864.4	3.7	62.49	0.24	442
12	188.1	DM	5.41	12.55	52.97	0.21	979.1	3.9	65.52	0.19	445
13	194.8	DM	2.53	9.12	24.74	0.18	977.9	7.1	33.86	0.27	438
14	199.3	DM	6.94	12.67	53.18	0.18	766.3	2.6	65.85	0.19	442
15	209.2	DM	16.24	17.64	114.22	0.17	703.3	1.0	131.86	0.13	450
16	214.9	DM	4.15	7.62	32.67	0.21	787.2	5.1	40.29	0.19	436

No.	Depth (m)	Zone	Organic Carbon (Wt.%)	S1 (mg/gm)	S2 (mg/gm)	S3 (mg/gm)	H Index	O Index	Oil/Gas Poten. (S1+S2)	Prod. Index (S1/(S1+S2))	Tmax (°C)
17	237.7	DM	4.96	8.93	41.54	0.25	837.5	5.0	50.47	0.18	443
18	242.0	DM	15.82	17.92	130.81	0.45	826.9	2.8	148.73	0.12	446
19	246.9	DM	2.57	6.16	20.98	0.16	816.3	6.2	27.14	0.23	438
20	256.0	DM	6.51	9.51	51.92	0.27	797.5	4.1	61.43	0.15	441
21	283.2	DM	6.18	12.25	61.08	0.20	988.3	3.2	73.33	0.17	444
Canadian Occidental Petroleum Albert Mines 7											
1	32.0	HB	3.90	4.47	35.58	0.20	912.3	5.1	40.05	0.11	447
2	56.7	HB	4.42	6.55	40.74	0.13	921.7	2.9	47.29	0.14	446
3	108.8	AM	4.72	8.03	41.39	0.13	876.9	2.8	49.42	0.16	448
4	115.8	AM	6.75	10.52	52.52	0.10	778.1	1.5	63.04	0.17	448
5	158.8	DS	1.43	1.67	5.25	0.13	367.1	9.1	6.92	0.24	440
5A	212.8	RH	1.24	7.88	10.74	0.12	866.1	9.7	18.62	0.42	428
6	234.4	RH	7.33	4.17	68.42	0.18	933.4	2.5	72.59	0.06	451
7	357.8	DS	5.39	3.86	44.35	0.15	822.8	2.8	48.21	0.08	446
8	409.0	RH	0.95	2.63	6.81	0.06	716.8	6.3	9.44	0.28	437
9	442.3	RH	1.29	3.06	8.78	0.25	680.6	19.4	11.84	0.26	437
AtlanticRichfield Boudreau 1											
1	132.9	HB	0.44	0.77	0.18	0.28	40.9	63.6	0.95	0.81	428
2	147.8	HB	1.35	5.47	13.02	0.16	964.4	11.9	18.49	0.30	426
3	195.1	US	1.46	0.54	6.43	0.35	440.4	24.0	6.97	0.08	439
4	261.5	US	2.96	0.93	23.12	0.31	781.1	10.5	24.05	0.04	444
5	289.0	US	0.61	0.28	1.29	0.36	211.5	59.0	1.57	0.18	435
6	302.8	AM	5.24	2.25	46.49	0.39	887.2	7.4	48.74	0.05	441
7	315.2	AM	4.03	2.44	38.20	0.28	947.9	6.9	40.64	0.06	444
8	371.9	AM	8.97	4.33	83.51	0.34	931.0	3.8	87.84	0.05	445
9	375.8	AM	3.95	3.61	34.42	0.37	871.4	9.4	38.03	0.09	442
10	379.2	AM	13.04	4.73	111.28	0.38	853.4	2.9	116.01	0.04	450
11	433.1	DM	9.42	4.35	93.95	0.47	997.3	5.0	98.30	0.04	444
12	443.2	DM	12.94	4.31	124.60	0.42	962.9	3.2	128.91	0.03	447
13	475.5	DM	1.41	1.80	9.70	0.21	687.9	14.9	11.50	0.16	438
14	481.3	DM	7.23	3.52	71.23	0.41	985.2	5.7	74.75	0.05	442
15	551.4	RH	10.97	4.84	81.14	0.55	739.7	5.0	85.98	0.06	448
AtlanticRichfield Dover 1A											
1	34.1	US	6.89	3.43	68.34	0.38	991.9	5.5	71.77	0.05	443
2	40.9	US	3.09	1.46	15.76	0.60	510.0	19.4	17.22	0.08	436
3	191.1	DM	4.71	2.61	42.83	0.36	909.3	7.6	45.44	0.06	443
4	198.7	DM	2.00	1.23	11.94	0.40	597.0	20.0	13.17	0.09	440
5	202.7	DM	9.16	6.03	85.50	0.42	933.4	4.6	91.53	0.07	445
Canadian Occidental Petroleum Rosevale 1											
A	310.9	HB	1.70	1.66	9.37	0.17	551.2	10.0	11.03	0.15	442
B	314.6	HB	0.75	0.56	1.57	0.14	209.3	18.7	2.13	0.26	441
1	512.7	HB	1.73	2.21	8.86	0.23	512.1	13.3	11.07	0.20	436
2	598.0	US	1.79	7.69	13.45	0.13	751.4	7.3	21.14	0.36	431
3	603.8	US	2.36	2.53	15.72	0.22	666.1	9.3	18.25	0.14	443

No.	Depth	Zone	Organic Carbon (Wt.%)	S1 (mg/gm)	S2 (mg/gm)	S3 (mg/gm)	H Index	O Index	Oil/Gas Poten. (S1+S2)	Prod. Index $\left(\frac{S1}{S1+S2}\right)$	Tmax (°C)
4	612.6	AM	4.13	3.14	38.78	0.17	939.0	4.1	41.92	0.07	448
5	632.5	CM	2.53	2.18	16.89	0.29	667.6	11.5	19.07	0.11	442
6	635.8	CM	4.18	3.17	39.45	0.17	943.8	4.1	42.62	0.07	445
AtlanticRichfield Urney 1											
1	71.9	AM	1.57	0.66	11.61	0.24	739.5	15.3	12.27	0.05	442
2	94.2	AM	1.21	0.68	7.68	0.23	634.7	19.0	8.36	0.08	443
3	106.7	AM	1.82	1.59	12.67	0.28	696.2	15.4	14.26	0.11	438
4	228.9	DM	4.51	2.23	44.53	0.30	987.4	6.7	46.76	0.05	448

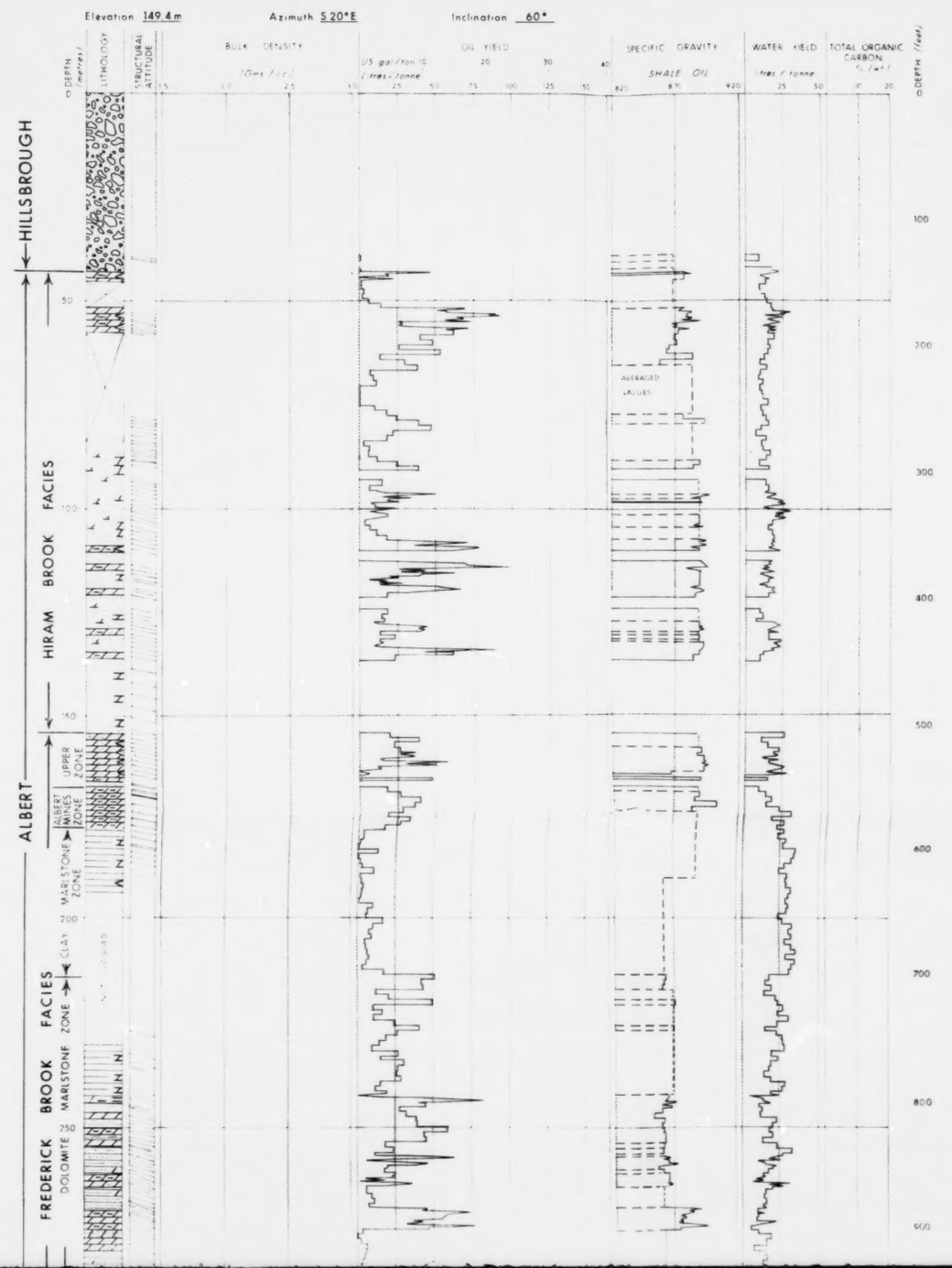
ATLANTIC RICHFIELD URNEY 1

Elevation 167.6 m Azimuth N45°W Inclination 45°



ATLANTIC RICHFIELD ROSEVALE 1

Elevation 149.4 m Azimuth S20°E Inclination 60°



ROSEVALE 1

60°

SPECIFIC GRAVITY
SHALE OIL

WATER YIELD
litres / tonne

TOTAL ORGANIC CARBON
% (wt)

DEPTH (feet)

ALTERED VALUES

100
200
300
400
500
600
700
800
900

CANOXY ROSEVALE 1

Elevation 228.6m ± Azimuth ____ Inclination 90°

DEPTH (metres)

LITHOLOGY

STRUCTURAL ATTITUDE

BULK DENSITY
(Gms / c.c.)

OIL YIELD
US gallon / ton
Litres / tonne

SPECIFIC GRAVITY
SHALE OIL

WATER YIELD
litres / tonne

TOTAL ORGANIC CARBON
% (wt)

SAMPLE NUMBER

DEPTH (feet)

HILLSBOROUGH

CAVED

50
100
150
200
250
100
200
300
400
500
600
700
800
900

ATLANTIC RICHFIELD BOUDREAU 1

Elevation 30.5m ± Azimuth S45°E Inclination 50°

DEPTH (metres)

LITHOLOGY

STRUCTURAL ATTITUDE

BULK DENSITY
(Gms / c.c.)

OIL YIELD
US gallon / ton
Litres / tonne

SPECIFIC GRAVITY
SHALE OIL

HIRAM BROOK FACIES

UPPER ZONE

AVERAGED VALUES

50
100
150
200
250

ATLANTIC RICHFIELD BOUDREAU 1

Elevation 30.5m ± Azimuth S45°E Inclination 50°

BULK DENSITY (Gms/cc) | OIL YIELD US gallon/ton, Litres/tonne | SPECIFIC GRAVITY SHALE OIL | WATER YIELD Litres/tonne | TOTAL ORGANIC CARBON % wt | LITHOLOGY | STRUCTURAL ATTITUDE | DEPTH (metres) | DEPTH (feet) | SAMPLE NUMBER

HIRAM BROOK FACIES

UPPER ZONE

ATLANTIC RICHFIELD DOVER 1A

Elevation 59.4m Azimuth N25°E Inclination 60°

BULK DENSITY (Gms/cc) | OIL YIELD US gallon/ton, Litres/tonne | SPECIFIC GRAVITY SHALE OIL | WATER YIELD Litres/tonne | TOTAL ORGANIC CARBON % wt | LITHOLOGY | STRUCTURAL ATTITUDE | DEPTH (metres) | DEPTH (feet) | SAMPLE NUMBER

ENRAGE

UPPER ZONE (?)

FREDERICK BROOK FACIES

ALBERT MINES ZONE (?)

CLAY MARLSTONE (?)

DOLOMITE MARLSTONE ZONE (?)

FREDERICK BROOK FACIES
CLAY MARLSTONE ZONE
DOLOMITE MARLSTONE ZONE
NO ADJUSTMENT FOR INCLINATION

ALBERT HIRAM
ALBERT MINES ZONE
UPPER ZONE
MARLSTONE ZONE
CLAY
FREDERICK BROOK FACIES
DOLOMITE MARLSTONE ZONE
DAWSON SETTLEMENT FACIES
NO ADJUSTMENT FOR INCLINATION

HILLSBOROUGH

ALBERT
HIRAM BROOK

LITHOLOGY

ROCK TYPES

MODIFIERS

INCLINATION

THOLOGY

MODIFIERS

ORGANIC

ORGANIC LAMINAE

CONGLOMERATIC

HILLSBOROUGH

ALBERT
HIRAM BROOK

Avg D

FREDERICK BROOK FACIES

UPPER ZONE

ALBERT MINES ZONE

CLAY

MARLSTONE

MARLSTONE

DOLOMITE

FREDERICK BROOK FACIES

DOLOMITE MARLSTONE ZONE (?)

CLAY MARLSTONE (?)

DAWSON SETTLEMENT FACIES

NO ADJUSTMENT FOR INCLINATION

FREDERICK BROOK FACIES

DOLOMITE MARLSTONE ZONE

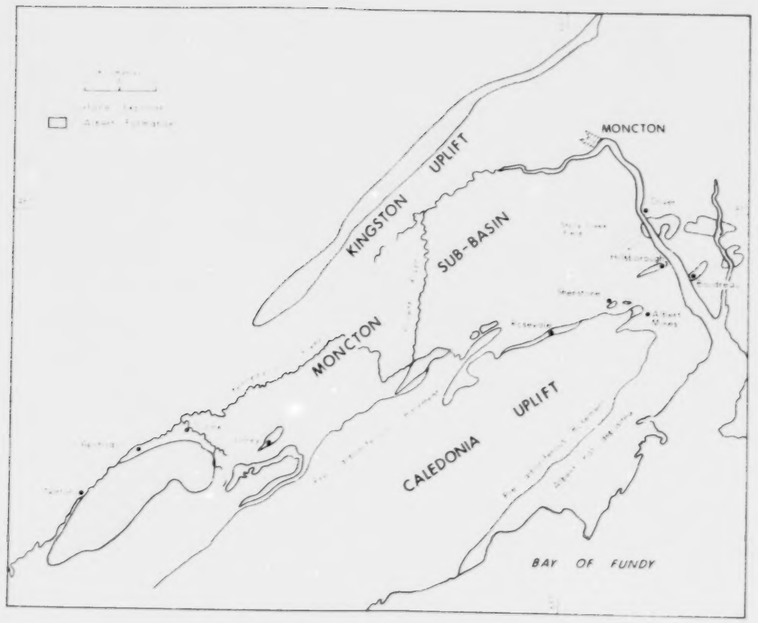
CLAY MARLSTONE

ALBERT MINES ZONE

UPPER ZONE

DAWSON

NO ADJUSTMENT FOR INCLINATION



LITHOLOGY

ROCK TYPES	MODIFIERS
LAMINATED MARLSTONE	ORGANIC
CLAY MARLSTONE	ORGANIC LAMINAE
DOLOMITE MARLSTONE	
CONGLOMERATE	CONGLOMERATIC
SANDSTONE	SANDY
SILTSTONE	SILTY
SHALE - CLAYSTONE	ARGILLACEOUS
DOLOSTONE	DOLOMITIC
LIMESTONE	CALCAREOUS

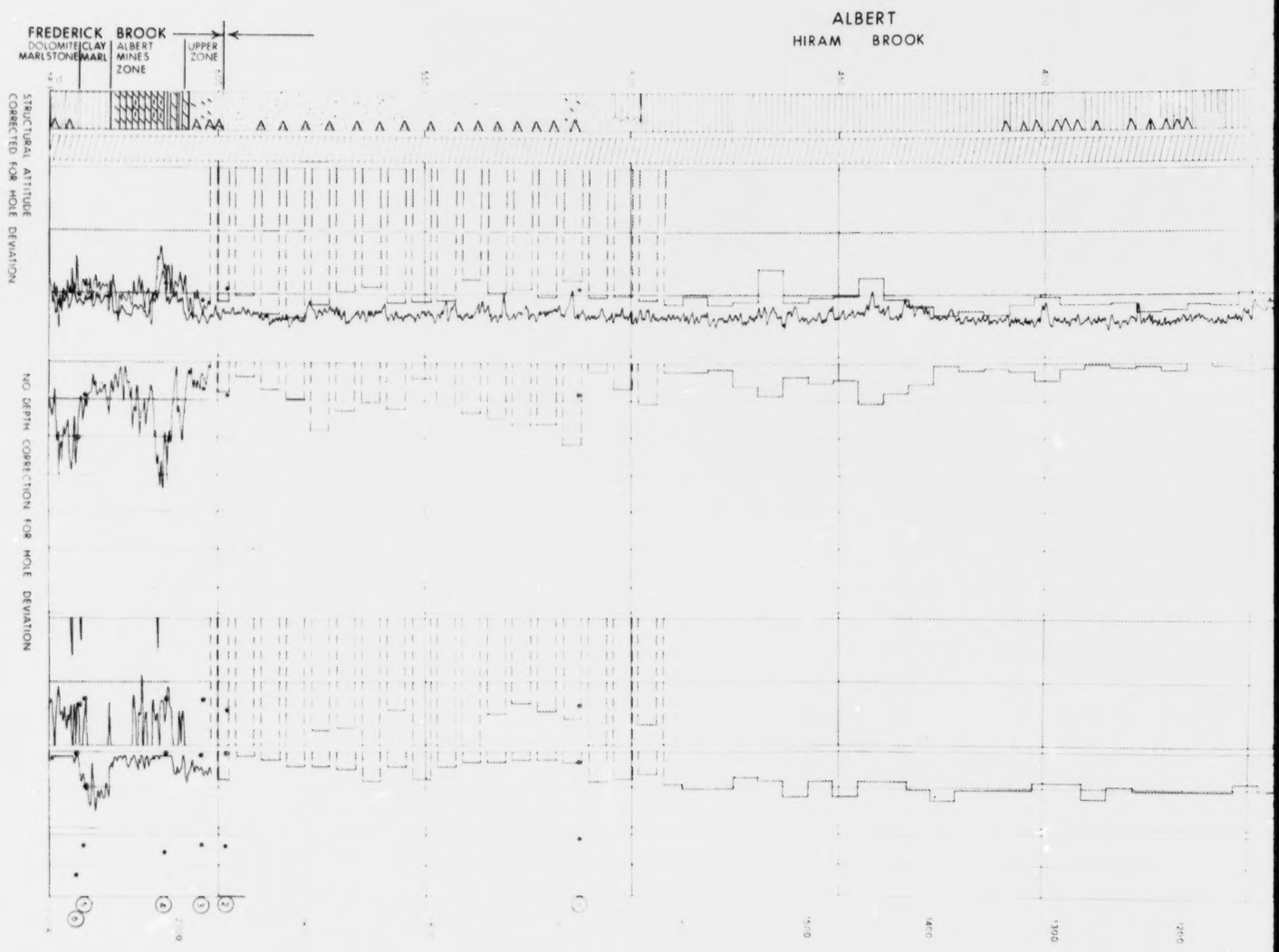
ASSAY DATA - CANOXY & ATLANTIC RICHFIELD PROGRAMS

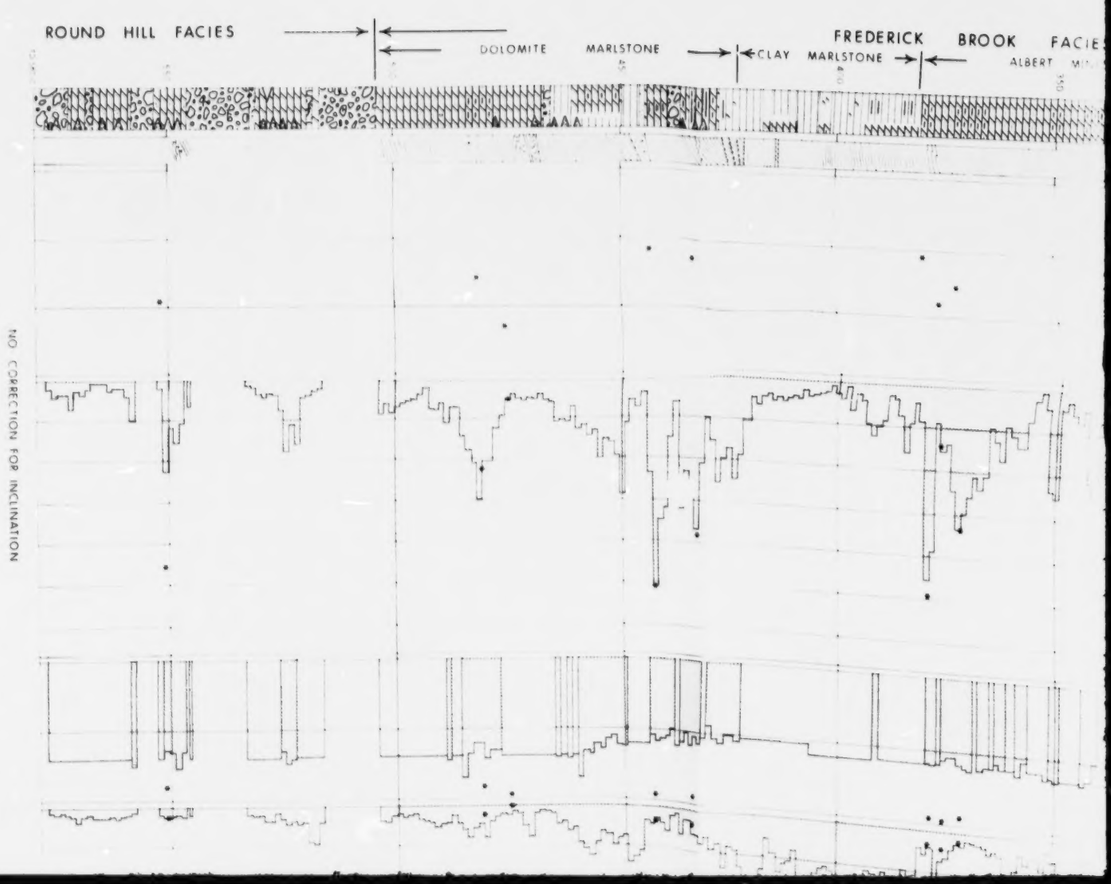
ASSAY DATA - SPOT SAMPLES THIS STUDY

DOWNHOLE DENSITY LOG

ALBERT
HIRAM BROOK

FREDERICK BROOK
DOLOMITE/CLAY MARLSTONE
ALBERT MINES ZONE
UPPER ZONE


FREDERICK BROOK
DOLOMITE MARLSTONE
CLAY MARL
ALBERT MINES ZONE
UPPER ZONE
ALBERT
HIRAM BROOK
STRUCTURAL ATTITUDE CORRECTED FOR HOLE DEVIATION
NO DEPTH CORRECTION FOR HOLE DEVIATION


ROUND HILL FACIES
DOLOMITE
MARLSTONE
CLAY
MARLSTONE
FREDERICK BROOK FACIE
NO CORRECTION FOR INCLINATION

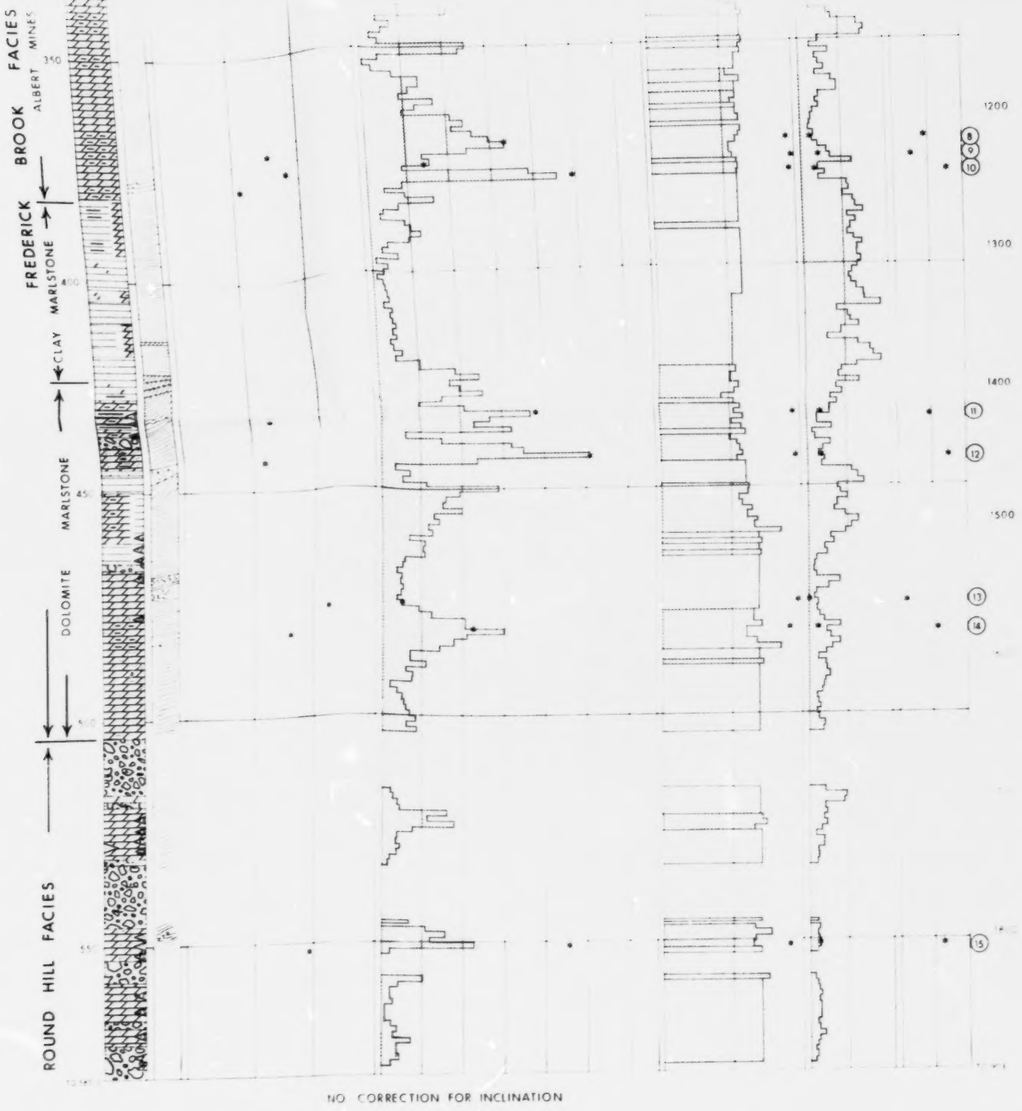


FIGURE 5
URNEY ROSEVALE AND BOUDREAU-DOVER
COREHOLE LOGS

CANOXY ALBERT MINES 7

CANOXY ALBERT MINES 6

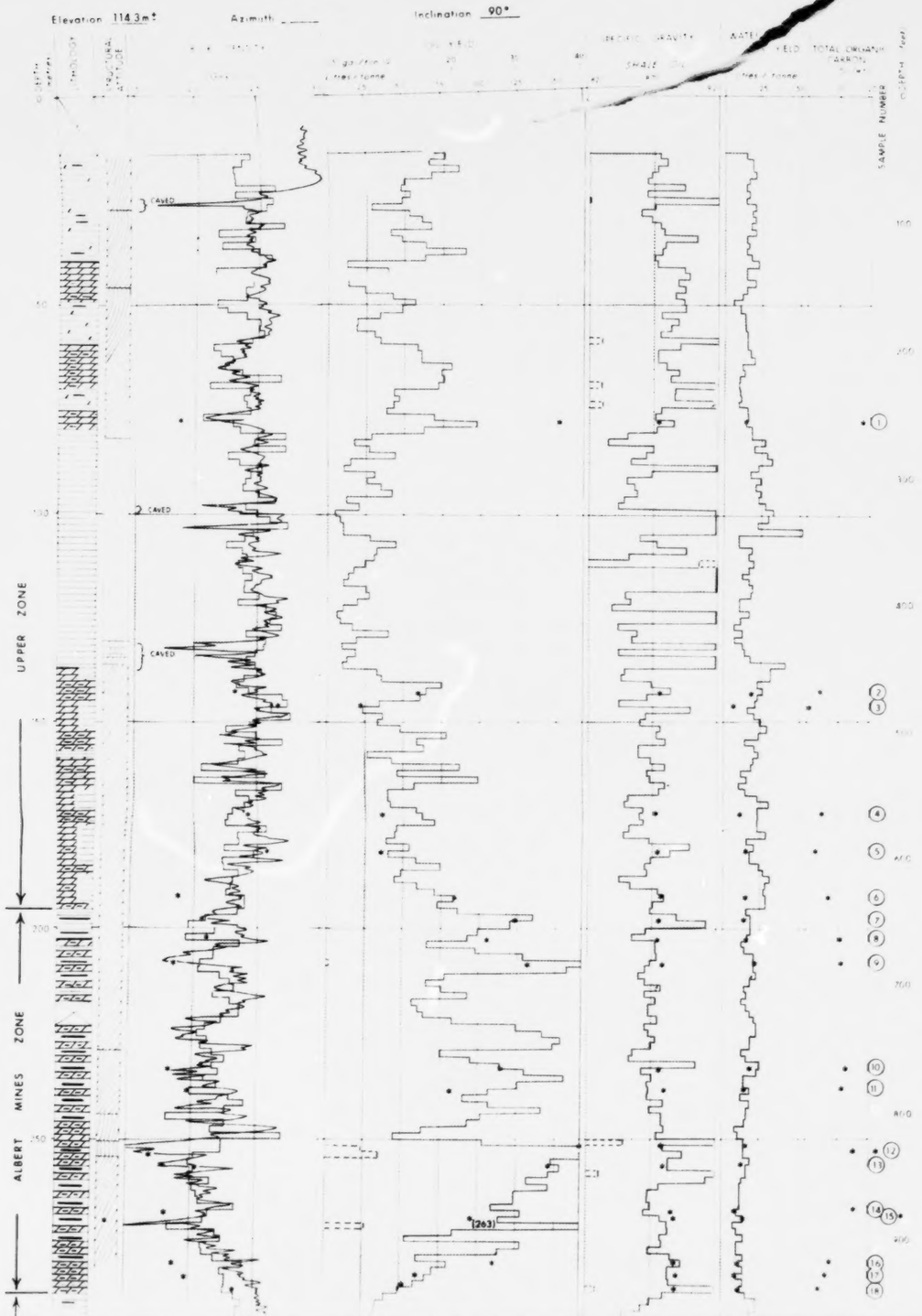
FREDERICK BROOK FACIES

DOLOMITE MARLSTONE

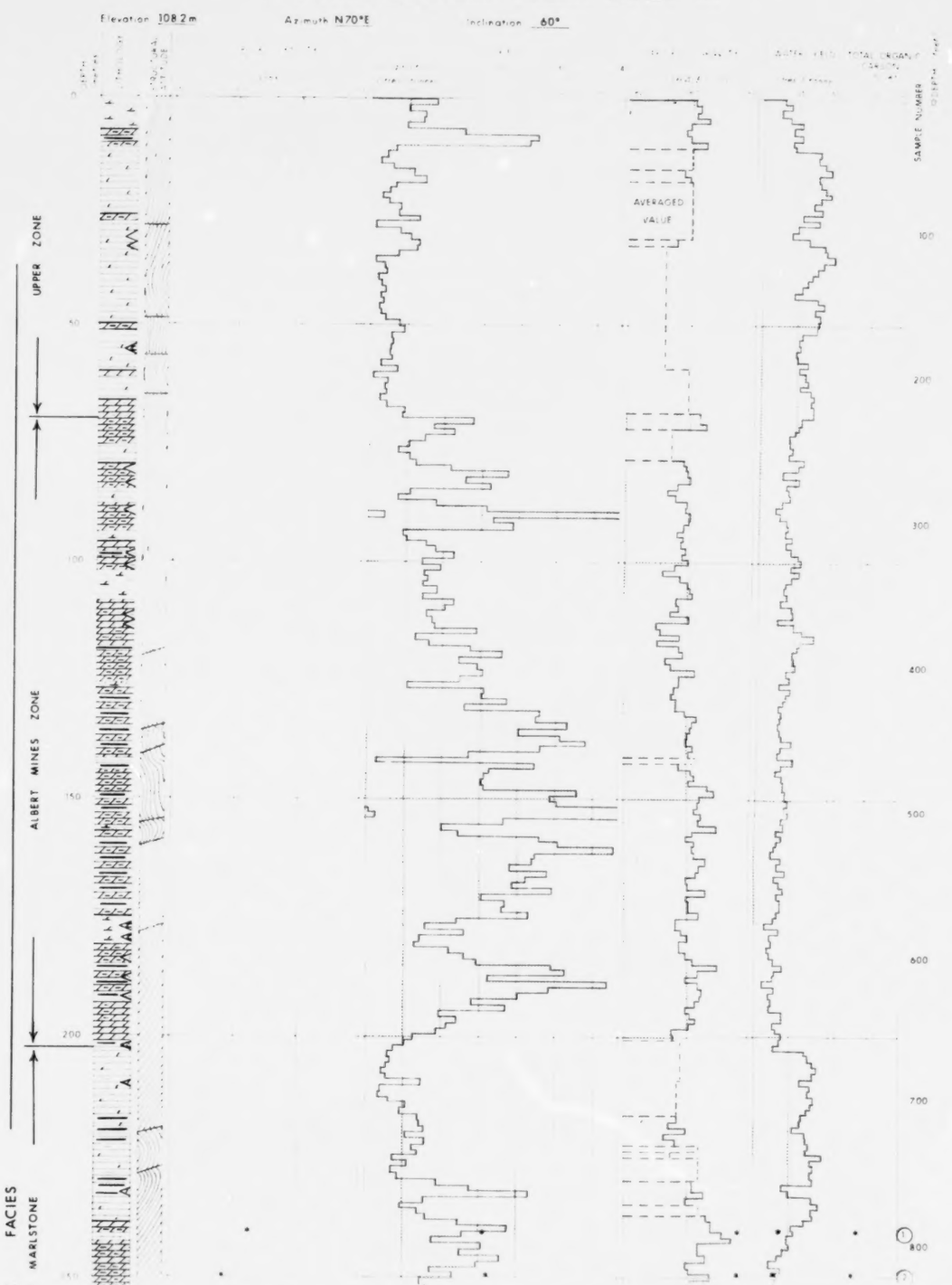
GRAY MARLSTONE

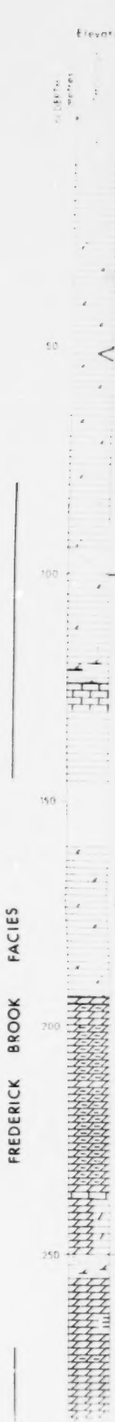
ALBERT MINES ZONE

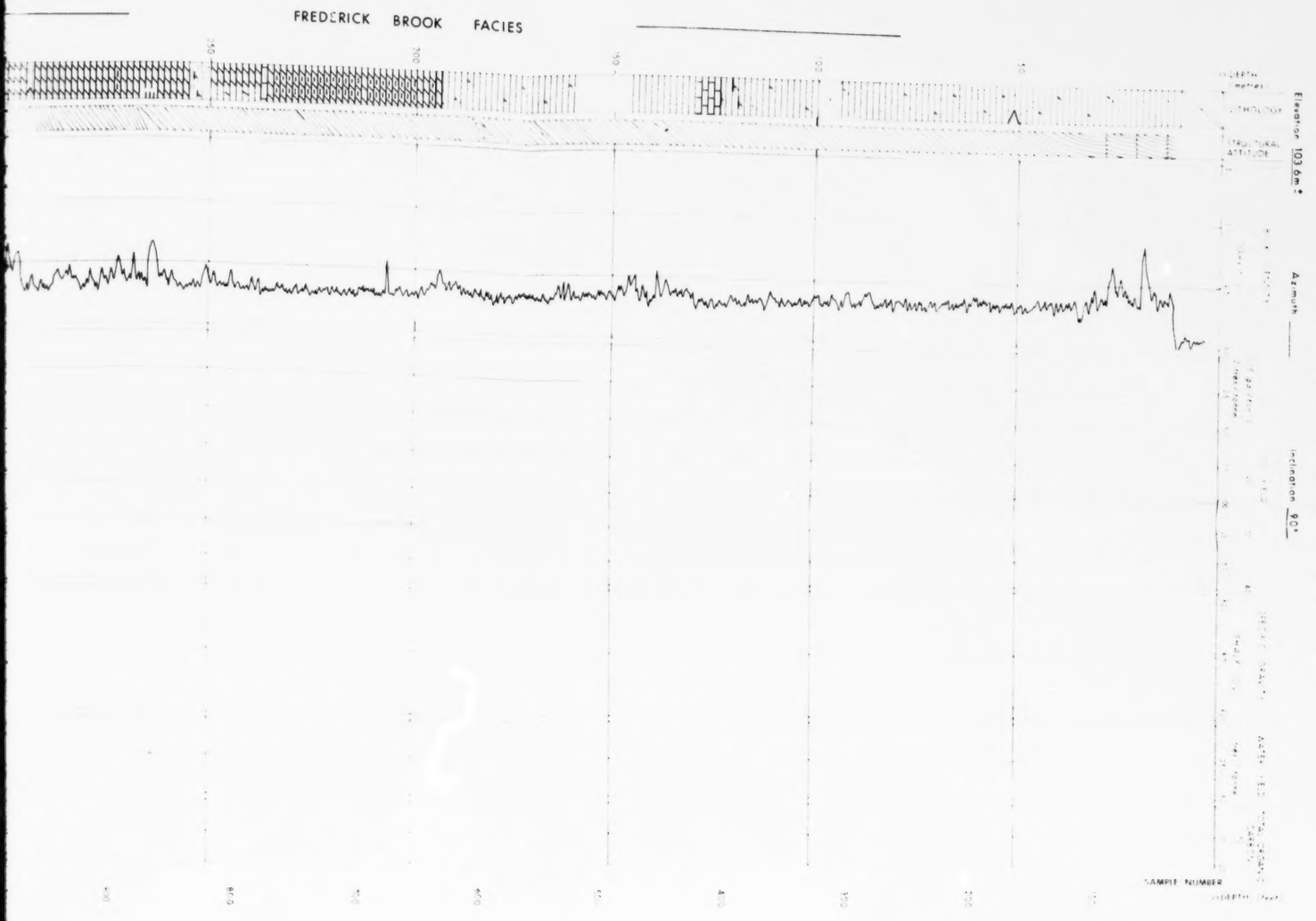
CANOXY ALBERT MINES 5

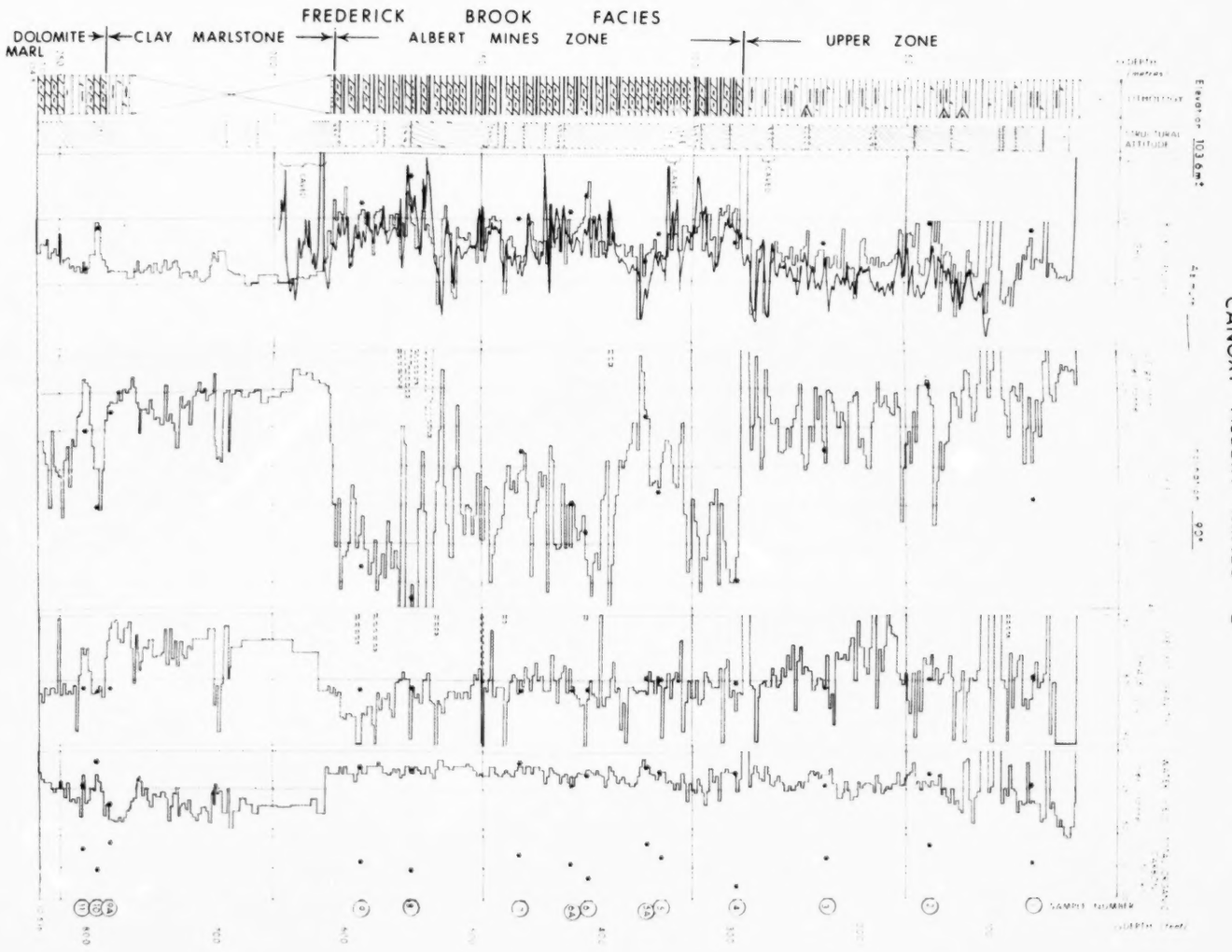


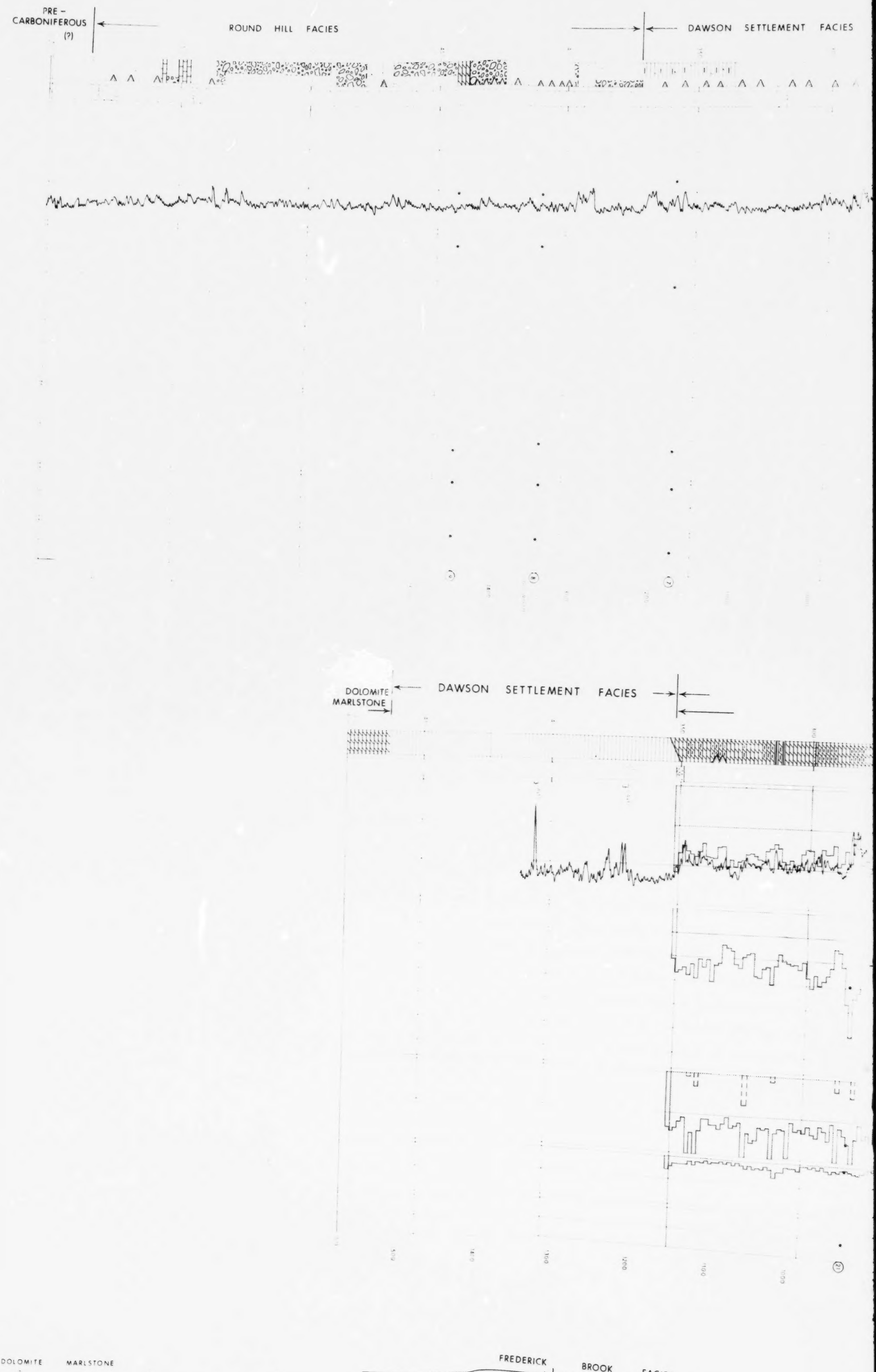
ATLANTIC RICHFIELD ALBERT MINES 1A

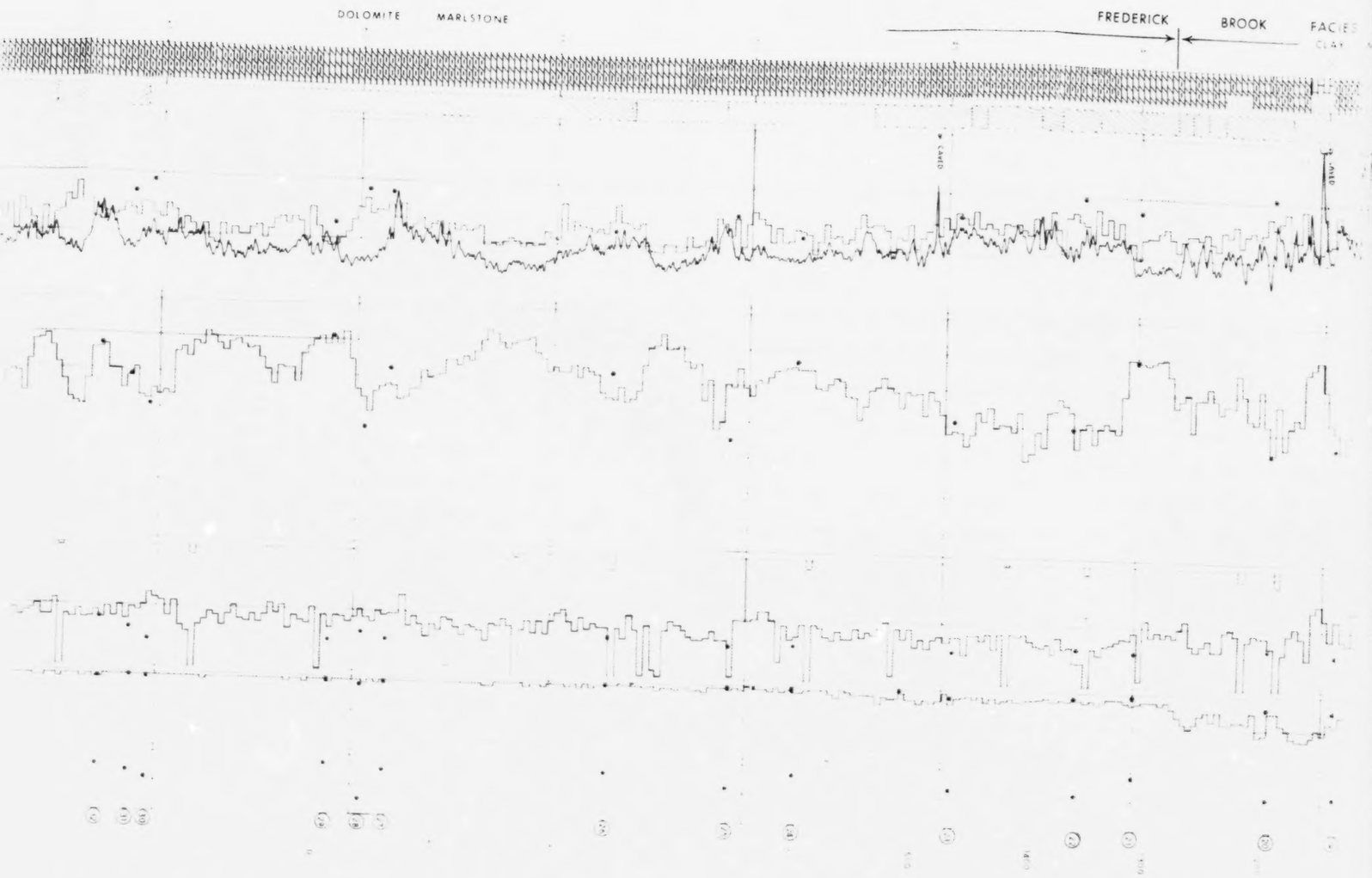


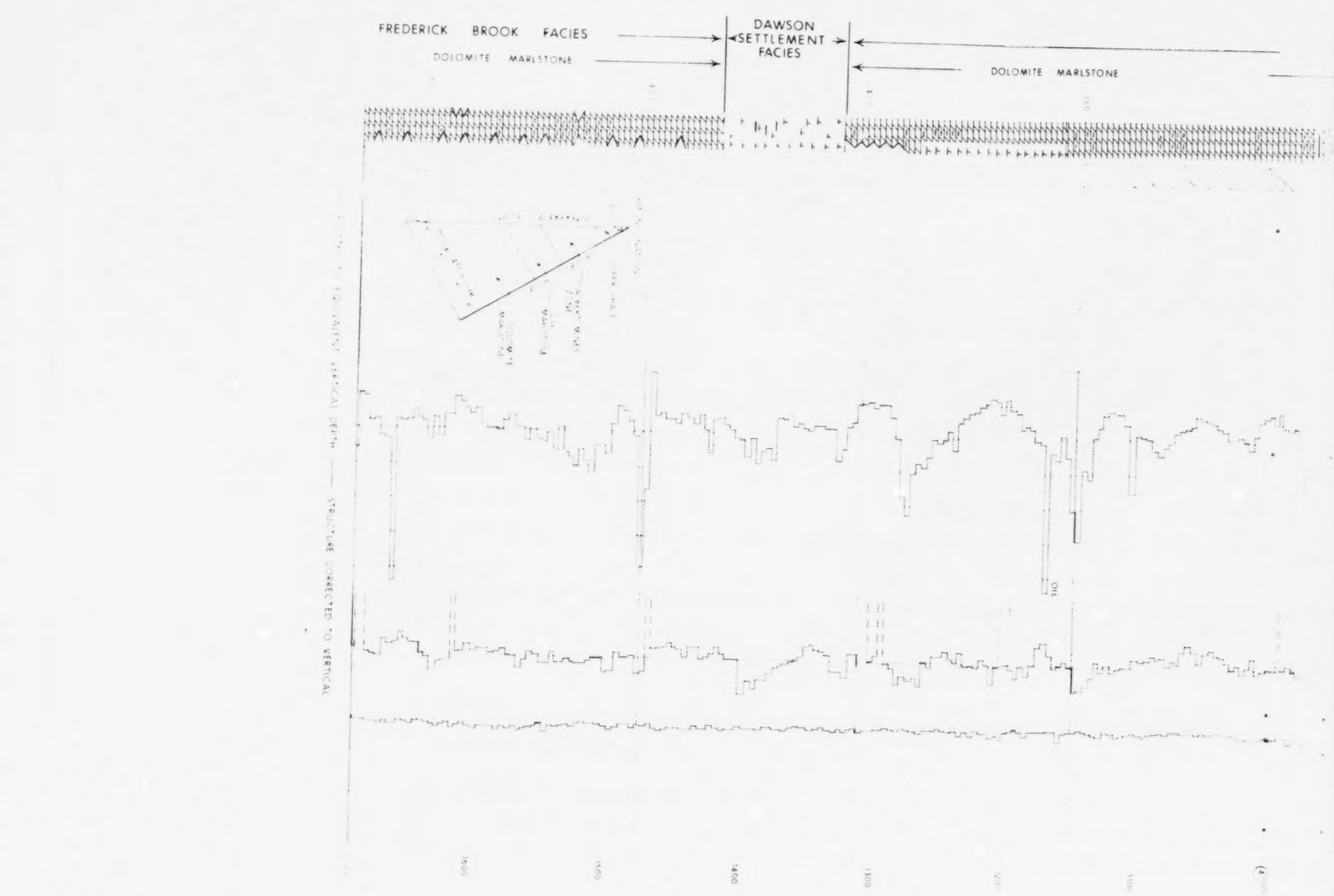


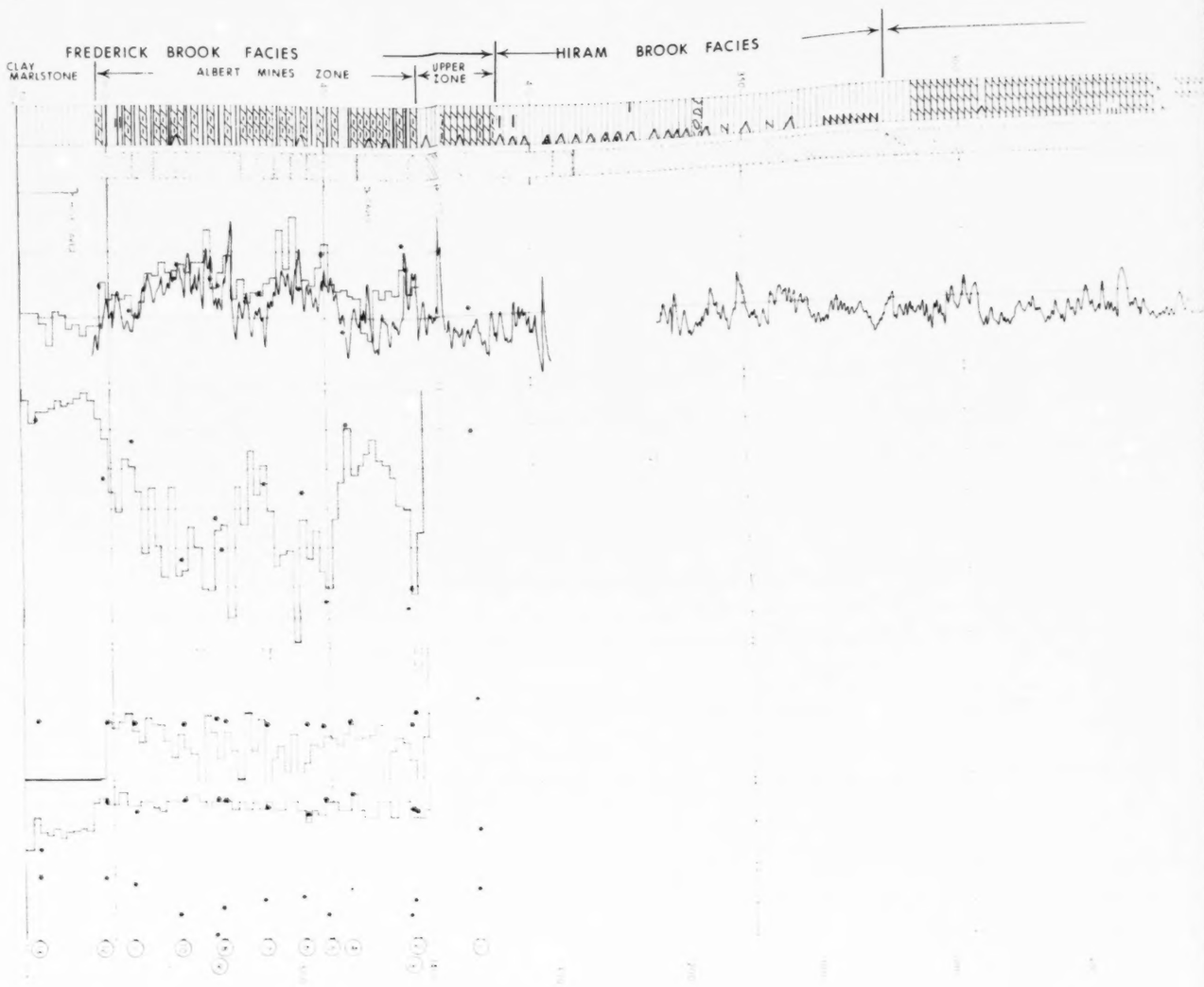

FREDERICK BROOK FACIES
CANOXY ALBERT MINES 4


DOLOMITE MARL
CLAY MARLSTONE
FREDERICK BROOK FACIES
ALBERT MINES ZONE
UPPER ZONE
CANOXY ALBERT MINES 2

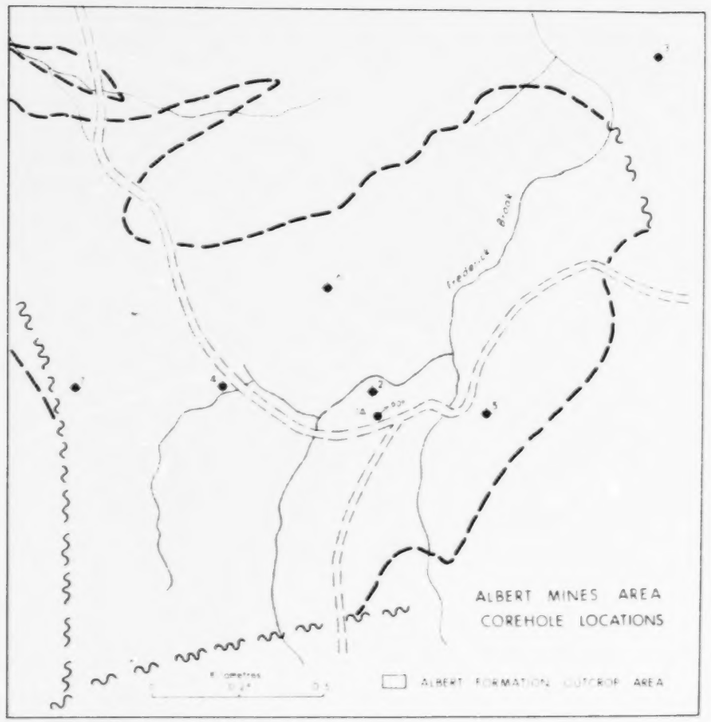

PRE – CARBONIFEROUS (?)
ROUND HILL FACIES
DAWSON SETTLEMENT FACIES
DOLOMITE
MARLSTONE
DAWSON SETTLEMENT FACIES
DOLOMITE
MARLSTONE
FREDERICK
BROOK
FACIES
CLAY
MARLSTONE


DOLOMITE
MARLSTONE
FREDERICK
BROOK
FACIES
CLAY


FREDERICK
BROOK
FACIES
DOLOMITE
MARLSTONE
DAWSON
SETTLEMENT
FACIES
DOLOMITE
MARLSTONE


FREDERICK BROOK FACIES
CLAY MARLSTONE
ALBERT MINES ZONE
UPPER ZONE
HIRAM BROOK FACIES

PRE-
CARBONIFEROUS
(?)



DOLOMITE

CONGLOMERATE

SANDSTONE

SILTSTONE

DOLOSTONE

LIMESTONE

LITHOLOGY

ROCK TYPES		MODIFIERS	
	LAMINATED MARLSTONE	—	ORGANIC
	CLAY MARLSTONE	——	ORGANIC LAMINAE
	DOLOMITE MARLSTONE		
	CONGLOMERATE		CONGLOMERATIC
	SANDSTONE		SANDY
	SILTSTONE	— —	SILTY
	SHALE - CLAYSTONE		ARGILLACEOUS
	DOLOSTONE		DOLOMITIC
	LIMESTONE		CALCAREOUS

ASSAY DATA - CANDOR & ATLANTIC RICHFIELD PROGRAMS

ASSAY DATA - SPOT SAMPLES THIS STUDY

DOWNHOLE DENSITY LOG

FIGURE 4
ALBERT MINES AREA
CORE HOLE LOGS